COMPARATIVE ANALYSIS OF MAIZE-LIVESTOCK INNOVATION SYSTEMS IN AWASSA, BAKO AND AMBO AREAS OF ETHIOPIA

PhD Dissertation

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Haramaya University

COMPARATIVE ANALYSIS OF MAIZE-LIVESTOCK INNOVATION SYSTEMS IN AWASSA, BAKO AND AMBO AREAS OF ETHIOPIA

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By
Ashenafi Mengistu

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HARAMAYA UNIVERSITY

As members of the advisory team of Mr. Ashenafi Mengistu, we certify that we have read and evaluated his dissertation entitled **"Comparative Analysis of Maize-Livestock Innovation Systems in Awassa, Bako and Ambo Areas of Ethiopia** "and recommend that the dissertation be accepted as fulfilling the requirements for the degree of **Doctor of Philosophy in Agriculture (Animal Nutrition).**

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DEDICATION

I dedicate this Dissertation to my late brother Adugna Mengistu who remains in the bottom of my heart as a symbol for dynamism though his untimely death separated us forever.

STATEMENT OF THE AUTHOR

First, I declare that this dissertation is my bonafide work and that all sources of materials used for this dissertation have been duly acknowledged. This dissertation has been submitted in partial fulfillment of the requirements for a PhD degree at the Haramaya University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this dissertation is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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ABBREVIATIONS AND ACRONYMS

ADF	Acid Detergent Fiber
ADL	Acid Detergent Lignin
ADLI	Agriculture Development Led Industrialization
CBOs	Community Based Organizations
CIMMYT	International Center for Wheat and Maize Improvement
CP	Crude Protein
DM	Dry Matter
EARO	Ethiopian Agricultural Research Organization
EEA	Ethiopian Economic Association
EEPRI	Ethiopian Economic Policy Research Institute
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization of the United Nations
FTCs	Farmers' Training Centers
GDP	Gross Domestic Product
GIS	Geographic Information System
HLIs	Higher Learning Institutions
IAR	Institute of Agricultural Research
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IVOMD	*In vitro* Organic Matter Digestibility
ME	Metabolizable Energy
MoARD	Ministry of Agriculture and Rural Development
NDF	Neutral Detergent Fiber
NGOs	Nongovernmental Organizations
NIRS	Near Infrared Reflectance Spectroscopy
NIS	National Innovation System
RARIs	Regional Agricultural Research Institutions
TVET	Technical and Vocational Education Training
USAID	United States Agency for International Development

BIOGRAPHICAL SKETCH

The author was born in Gojjam in 1968 from his father *Bilatta* Mengistu Wossen and his mother *Woizero* Adanech Workneh. He attended his elementary education at Agitta Eyesus Elementary School, and his junior and high school educations at Adet Junior and Senior Secondary School. After successful completion of high school education, he joined the then Alemaya University of Agriculture in 1985 and graduated with BSc degree in Animal Science in 1989. Right after graduation, he joined IAR (Intitute of Agricutural Research) and served at Adami Tullu Agricultural Research Center for four years. Then, he joined the School of Graduate Studies of Haramaya University in 1993/94 and obtained MSc degree in Animal Production in 1997. Again, he returned to Adami Tullu Research Center and worked there until November 2003. In the lapse of his research career, he served his institution from a level of Junior Researcher up to Associate Researcher II. In January 2004, he joined the Faculty of Veterinary Medicine of the Addis Ababa University with a rank of an Assistant Professor. In October 2006, he joined the School of Graduate Studies of Haramaya University to pursue his PhD study in Animal Nutrition. He is married and is a father of a daughter and a son.

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ABSTRACT

A study was undertaken with the objectives of (i) assessing farmers' practices in the use of maize byproducts for livestock feeding and analyze influence of variety on yield and quality of the stover; (ii) analyzing constraints and linkages between maize and livestock subsystems; (iii) assessing factors influencing farmers' preferences to improved maize varieties, and (iv) describing and understanding the maize-livestock innovation systems at a national level and in selected areas. The study included three levels of analysis, namely the macro, meso and micro levels. The macro level analysis focused on evaluating the national maize – livestock innovation system where key actors, their roles and competencies, their habits and practices, and linkages and interactions were analyzed through review of secondary sources and key informant interviews. The meso level emphasized on the analysis of the innovation systems in Awassa, Bako and Ambo areas, and the assessment of feeding practices and farmers' rankings of maize varieties through key informant interviews and focus group discussions. Stover samples that were collected at green/eshet and mature/dry stages from on-farm demonstration plots were analyzed for their chemical composition (ash, nitrogen, neutral detergent fiber, acid detergent fiber, acid detergent lignin, in vitro organic matter digestibility and metabolizable energy). Besides, at micro level, household level data were collected from a total sample size of 350 farmers randomly selected from Awassa, Bako Tibe and Ambo districts. Analysis of factors that affect farmers' choice of varieties was done using the multinomial logit model. Descriptive statistics and ANOVA were also employed as analytical tools. From the studied maize varieties, significant varietal differences were observed in NDF and ADL contents of stovers. However, varietal difference in grain yield was not significant. Results of the current study gave indications about the possibility of manipulating feed related traits in the effort to breed and/or select for maize varieties that combine food and feed traits The linkage between the maize and livestock subsystems towards an integrated maize-livestock production system has been constrained by several problems. These constraints affect resource flows between the two subsystems by constraining both or either. These included socio economic, biophysical and institutional constraints. The ever intensifying population pressure which influences the availability of land for maize production and grazing and large family size of households motivating farmers to

cultivate more land dictated by the demand for enough grain are affecting the linkage. Feed shortage coupled with disease problems causes continuous decline of livestock number and productivity constraining the contribution of livestock to the maize subsystem. Unbalanced research and extension focus between the maize and the livestock subsystems, difficulties in the process of technology popularization and inefficient and ineffective input, credit and veterinary services are the important institutional bottlenecks for integrating the maize and livestock subsystems to the level they could. Analysis of the factors that affect farmers' choice of maize varieties gave results with a possible implication that livestock owning farmers make a preference to a variety with better stover quality in addition to grain yield. There were no functional and meaningful mechanisms of interaction between the actors in the maize livestock innovation system and the different actors have capacity limitations to execute their roles up to the level and quality that the system requires for being effective, efficient and sustainable. The overall picture of the maize-livestock innovation system is tied with the conventional top-down approach which is not participatory and learning based. The system suffers from shortages and high prices of inputs added to lack of timely supply. Lack of proper input demand assessment is also contributing to the scope of the problem. There is a high government control over the input system. Continued capacity building efforts for all of the actors and promotion of trust worthy interactive learning processes for better technological uptake and responsiveness to the demands of end users are necessary. An institutional innovation and building the culture of working together to bring about technological change is required.

1. INTRODUCTION

The crop-livestock system is the most dominant land use system in Ethiopia where there is a great deal of interdependence between livestock and crops in food production and natural resource conservation. In this system, land holding per household has been seriously declining due to the steadily increasing population pressure. The largest share of the arable land goes to crop cultivation with a shrinking size of grazing land. Forage technologies have failed to be widely adopted by farmers in the country as is common to tropical developing countries (Mannetje, 1997 as cited by Reddy *et al*. 2003), due to inadequate technical support and lack of appropriate and sufficient input supply particularly forage seed. These make livestock depend more on crop byproducts for their feed source. The increasing dependence of ruminant livestock on crop residues calls for greater innovation through integration of crop and livestock production since livestock also greatly influence the ability of farmers to produce food and cash crops through draft power, cash availability and manure.

Maize is the second dominant crop next to teff (*Eragristis teff*) among the cereals that are grown in Ethiopia. According to Dowswell *et al*. (1996), maize contributes more than 15% of the calorie intake of Ethiopians while EARO (2001a) puts this contribution at about one third of the total caloric intake nationally. Maize has been showing an increasing trend of production, productivity and diversity of ecological coverage since its introduction to Ethiopia during the 1600s and 1700s. For example, from the 1994/95 to the 1995/96 cropping season alone, the percentage increases observed in total area under maize production, total production and yield per ha were about 16, 52 and 31, respectively (CSA, 1996). Maize contributes a significant amount of fodder in the form of green or dry stover for livestock feeding more importantly in the major maize growing areas. The yield and quality of the residue are determined by the genetic makeup of the crop, growing and harvesting conditions, threshing and storage methods. Increasing demand for fodder, shortage of arable land and water together with shrinking and deteriorating common property resources is likely to put further pressure on feed resources. Failure of producers to feed animals adequately throughout the year continued to be the most critical constraint limiting livestock production and productivity. Shortage of feed causes forced sale of livestock (Berhanu *et al*., 2007b) which consequently affects overall agricultural production and productivity of a household by limiting the inputs/benefits that come from livestock. Improving the feed supply, both in quality and quantity, is an effective means to build assets and increase livestock productivity.

The need for food-feed maize cultivars that provide good stover fodder quantity and quality besides grain yield has been strongly voiced by researchers (Adugna, 2002; Devendra and Pezo, 2004; Singh *et al*., 2004). If varieties of maize that are of dual purpose are generated, it is believed to be of great contribution to the integration of maize and livestock as a result of increased feed supply to farmers to feed their livestock. However, farmers' choices depend on many factors and it is important to consider the farmers' capacity to innovate and farmers' choices as a function of the characteristics of the innovation system of which they are part. It is believed that decisions to innovate are often conditioned by the behaviour of individuals and the social and economic contexts within which decisions are made (Spielman, 2005).

Ethiopia's agricultural research system has put emphasis on knowledge/technology generation to be disseminated by the extension system. Innovation, the productive use of knowledge for desired social and economic benefits, has not been the focus causing important research outputs to remain shelved and/or poor and patchy adoption of technologies of maize (Abdissa *et al*., 2001; Tesfaye *et al*., 2001; Doss *et al*., 2003) and livestock (Azage *et al*, 2006). The government has been making significant investments to strengthen the agricultural research and extension system with the aim of reducing poverty through technological changes. However, there is an increasing recognition that the value of traditional agricultural science and technology investments, like research and extension, is not sufficient to enable agricultural innovation (World Bank, 2006). The innovation systems concept emerged as a response to the limited explanatory power of conventional economic models that view innovation as a linear process driven by the supply of research and development (Hall *et al*., 2006). The framework is now being used to understand and strengthen innovation at national and sector levels. Innovation systems are very important determinants of technological change. Traditional methods of innovation that mainly focus on the structure of innovation systems have proven to be insufficient (Hekkert *et al*., 2007). This insufficiency has resulted in the development of new techniques of evaluating innovation systems focusing on a number of processes that are important for well performing innovation systems. Innovation creates new opportunities, and these opportunities may not be realized or converted into economic activity until the prerequisite inputs (resources and skills) and product markets are in place (Carlsson *et al.*, 2002).

A working definition of the successful maize-livestock innovation system can be the process of using newly generated or already existing knowledge and associated services in productive ways (for market and non-market functions) by farmers in the mixed maize-livestock production system. It is constituted by overlapping flows of knowledge and relationships across a diverse set of actors in the maize and livestock sectors, their actions and interactions - together with the underlying institutions and policies - whose combined effectiveness helps define the extent to which new products, processes, and new forms of organization are translated into social and economic use. In this context, the innovation systems concept focuses attention on the broad range of players involved in the process of innovation – farmers, scientists, traders, development workers, policy makers, etc. It recognizes that innovation and the creation of novelty takes place through the interaction of these players and the process of knowledge sharing and learning that this interaction allows. The capacity to innovate and use knowledge productively is therefore a function of patterns of interaction and the factors that pattern these interactions – usually the habits and practices (or institutions in the sense of norms and rules) that shape the behaviour of different players (World Bank, 2006).

The potentiality of promoting agricultural development to reduce poverty and ensure food security in Ethiopia is enormous. Though there have been official reports that indicate a two-digit total economic growth in the last five years (MoFED, 2009), with agriculture being among the top sectors contributing to this growth, per capita agricultural GDP growth is slightly positive or stagnant (Byerlee *et al*., 2007). Accelerated per capita GDP growth aiming at food security and overall economic growth requires efforts of agricultural intensification supported by appropriate policies, technologies and other services. It also requires making a strategic refocus on selected commodities that could better respond to interventions. Several authors (Sumberg, 2003; Dorward *et al*., 2004; Diao and Pratt, 2007) have been advocating cereal based agricultural intensification to promote a poverty reducing economic growth in sub-Saharan Africa. As maize is the most productive among the cereal crops and can grow in diverse agro ecologies, it would be very reasonable if maize is considered as a strategic crop in the Ethiopian context. Despite the long history of maize research and extension efforts in Ethiopia where maize is considered as one of the most important commodity crops for food security (EARO, 2001a), adoption of maize technologies has been constrained by several problems. Maize technology adoption rate in the country is the least by East African standard. It has been reported to be as low as 21 % of the available maize area in 2006/07 (Langyintou *et al*., 2008). However, there have been reports (Abdissa *et al*., 2001; Diao and Pratt, 2007) that if farmers use improved technologies with improved seed and fertilizer, the existing maize production in Ethiopia could be doubled.

Most of the maize production comes from the mixed crop-livestock system produced by smallholders (CSA, 2008) using inputs like draught power, cash and manure from the livestock sub-sector. The use of draught power for cultivation and pack animals for transporting maize produce is the most important contribution of livestock to the maize enterprise. However, the productivity of livestock is severely constrained by feed shortage threatening the magnitude and sustainability of the contribution of livestock to maize production and productivity. Therefore, integrating maize and livestock through improving the contribution of maize to livestock feeding, and vice versa, would be a useful option to maintain a positive balance between the two enterprises and achieve sustainability. Thus, studying the system using the innovation systems framework enables to identify constraints and opportunities of the system and give recommendations on how to alleviate the constraints and make effective use of the opportunities to the benefit of the poor maize-livestock farmers and the country at large. Furthermore, assessment of the livestock feeding practices of farmers on maize stover and farmers' preferences to and perceptions about maize varieties with different stover characteristics as feed in addition to grain yield helps understand the extent of demand for dual purpose maize varieties and their potential uptake to inform future research and development planning processes.

Adugna *et al*. (1999) studied the effect of variety on the yield and quality of maize stover using eight maize varieties grown at Awassa and indicated the possibility of combining food and feed traits in maize. However, they cautioned about the interpretation of the results as the results were of a single season and one location. Therefore, it is important to look into issues of varietal difference on the yield and quality of maize stover by incorporating larger number of varieties and/or more locations. Moreover, data on the yield and quality of maize varieties are required to explain farmers' ratings or perceptions about the feed values of the varieties they experienced.

Thus, this study was conducted with the following general and specific objectives:

General objective: To assess the linkage between maize and livestock production and associated factors which influence the processes of maize- livestock integration.

Specific objectives:

1. To assess farmers' practices in the use of maize byproducts for livestock feeding and analyze influence of variety on yield and quality of the stover;
2. To analyze constraints to the linkages between the maize and the livestock subsystems;
3. To assess factors influencing farmers' preferences to improved maize varieties; and
4. To describe and understand the maize-livestock innovation systems at a national level and in selected areas.

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2. REVIEW OF LITERATURE

2.1. The Evolution and Status of Maize Production in Ethiopia

Originated in Central America, maize was introduced to West Africa in the early 1500s by Portuguese traders. Maize is the world and Africa's most adapted food crop, thriving in many environmental conditions and farming systems. It was introduced to Ethiopia during the 1600s to 1700s and remained a garden plant for centuries (McCann, 2005). Maize emerged as a field crop in the twentieth century along the southern edge of the Ethiopian highlands where commercial production began in the 1930s and a coffee-maize economy developed after World War II. The farmers controlled the crop selection on their plots, developing a conservative agrarian culture with their mix of cereals. Government controls on coffee during the socialist era, 1974-1991, persuaded many farmers to expand their maize crop (McCann, 2005).

Maize production in Ethiopia is totally rainfed and the bulk of the production (94%) is obtained in the long rainy season and small quantity from short rains. It grows from moisture stress areas to high rainfall areas and from the lowlands to the highlands (Kebede *et al*., 1993). This can be seen in Figure 1 which shows the zones that are suitable for growing maize in Ethiopia. Almost all the maize is produced for human consumption. Some quantity is used in the milling and feed processing industries (Diriba *et al*., 2001). The stover and the thinnings when green are used for livestock feeding. Stalks are used as a source of fuel and for construction. The grain is also one of the important cereals for household income generation.

Mosisa *et al*. (2001) indicated successive increases in the production and productivity of maize and area it covered between 1990 and 2000. They stressed that the availability of improved maize technologies combined with new extension program played a great role in the increment of maize production in the 1990s. However, it was apparent from their report that much of the increase in maize production during these years has come from increased maize acreage and not necessarily increased productivity.

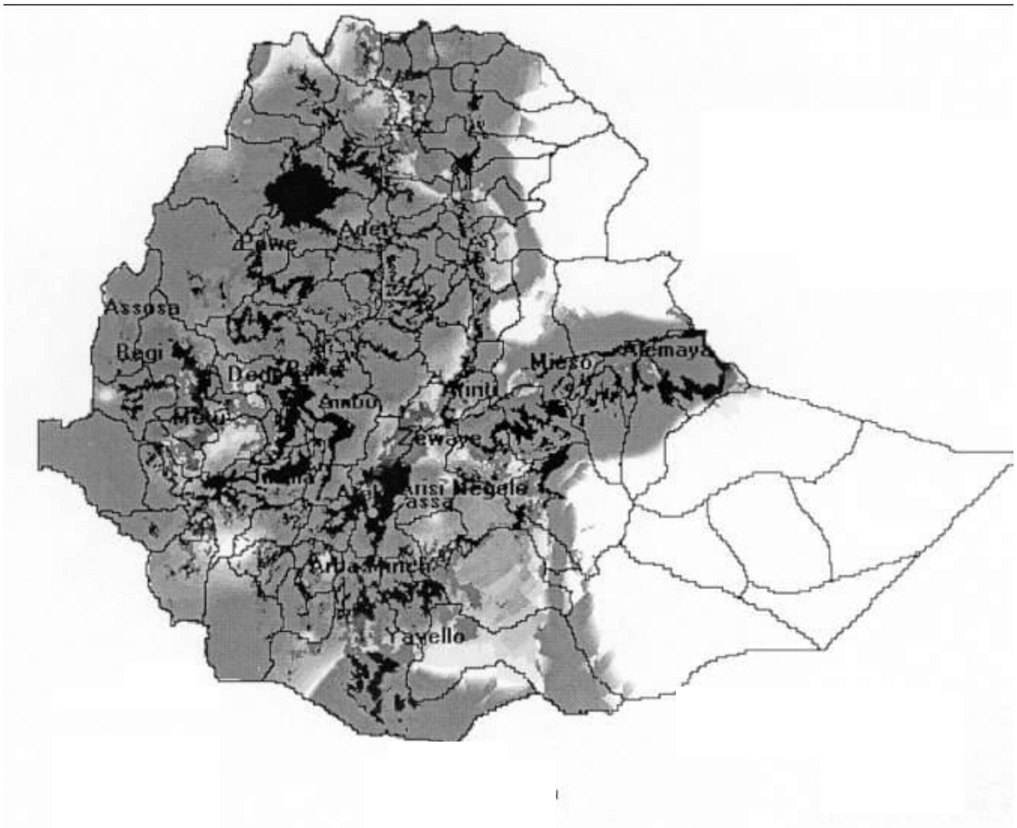

Figure 1. Maize growing zones of Ethiopia (Firew and Girma, 2001); Suitability increases from the light to the dark area

The improvement in productivity that has been reported is not commensurate with the steady growth in human population. There are many hungry mouths that need to be fed. The internationally reported growth of agricultural production in Africa as a whole does not exceed 2% per annum whereas population grows at 3% (Byerlee and Heisey, 1996). The mismatch requires enormous national and international efforts towards improving the performances of the agricultural sector through technology generation and its effective use for production and other purposes which, as we shall argue, depends on the effectiveness of partnerships, interactions and learning along with changes in institutional and organizational setups. Given its productivity, the relatively very large area available for crop production in the country and the immense potential for irrigated agriculture, maize is the most important cereal crop on which the country's efforts towards food security would rest.

2.2. Maize Research and Extension in Ethiopia

Technical change to increase food production is the most pressing need for addressing economic growth, alleviating poverty and arresting environmental degradation in most of sub-Saharan Africa (Byerlee and Heisey, 1996). According to the same authors, technical progress in maize production is central to these efforts.

In Ethiopia, research on maize was initiated at Jimma Junior Agricultural College in 1952. Thereafter, maize trials were planted at Debre Zeit Experiment Station. In the mid-1950's, formal research on maize began at the then Alemaya College of Agriculture and Mechanical Arts in the Eastern region. In addition to teaching responsibilities, agricultural colleges were the pioneers of research in Ethiopia. At this early stage, maize germplasm was evaluated and foundation concepts of practical field experimentation were laid. In 1966, the Institute of Agricultural Research (IAR) was officially set up to formulate a national research policy and coordinate agricultural research. In the same year, Bako Agricultural Research Station was established in the western region under an agreement between the government of Ethiopia and the Federal Democratic Republic of Germany. In the southern region, Awassa research center was established with aid from the French government in 1967. At present maize research is nationally coordinated by a team that is composed of several research disciplines.

Alemaya, Bako and Awassa were the ones involved in the release of several elite inbred lines of maize. About 16 improved maize varieties have been recommended for production for different agro-ecologies (EARO, 2001a). Table 1 presents the adaptation areas of 13 of the recommended maize varieties. The maize line which was designated as BH-140 was the first hybrid produced locally and released from Bako in 1988. Maize has been among the leading cereal grains selected as a national commodity crop in 1987 for its value to contributing to food self-sufficiency. With the introduction of the farming systems research approach, attempts were made to plan research based on farmers' priorities after conducting various diagnostic works. A team of professionals led the research planning process from the area of crop sciences, agricultural economics, and research and extension (EARO, 2001a). This effort was however narrowly focused on producing high-yielding maize varieties in terms of grain. The value of maize as an animal feed source was/has been considered as leftover by the researchers despite the fact that maize stover is traditionally one of the valuable feed resources for ruminant livestock in the mixed crop-livestock production system.

Table 1. Recommended maize varieties and their adaptation areas in Ethiopia.

Variety	Adaptation areas	
	Altitude (masl*)	Rainfall (mm)
A-511	500–1800	800–1200
UCB	1700–2000	1000–2000
Alemaya Composite	1600–2200	1000–1200
Katumani	1550	600–1000
ACV-3	1550	600–1000
ACV-6	1550	600–1000
Abo-Bako	500–1000	1000–1200
Kuleni	1700–2200	1000–1200
Gutto	1000–1700	800–1200
BH-140	1000–1800	1000–1200
BH-660	1600–2200	1000–1500
BH-540	1600–2000	1000–1200
BH-530	1000–1300	1000–1500

* masl = meters above sea level;
Source: EARO (2001a).

The maize innovation process was understood narrowly and has since been influenced by the linear transfer-of-technology model where innovation was equated to the generation of maize-related technologies by scientists at research stations followed by their release, packaging and dissemination by extension agents. The learning and feedback mechanisms between the organizations involved in this process continue to be very loose. Moreover, the technologies are recommended without due consideration of the diverse biophysical and socioeconomic situations of the end users. Consequently, it is not surprising to find reluctant farmers to adopt the technologies.

The adoption of maize technologies/varieties in Ethiopia has been reported by several authors to be patchy and poor (Legesse *et al*., 1989; Benti *et al*., 1996; Abdissa *et al*., 2001; Tesfaye *et al*., 2001; Doss *et al*., 2003). This has been ascribed to problems related to the efficiencies of support services. Problems in delivery and high cost of inputs, seasonality of output market and cash shortage have been reported to be the major bottlenecks in maize technology adoption. To this connection, the government tried to improve the efficiency of the support services through provision of inputs on credit (Belay, 1998) which resulted in a temporary increase in the number of farmers who try maize technologies on their fields. The importance of institutions, policy and infrastructure was somehow neglected except in Doss *et al.* (2003) where these issues have been seriously indicated. In a world of increasing specialization and interdependence, new kinds of relationships, organizations and institutions will be needed if people are to benefit and if growth and development are to be sustained (World Bank 1997 as cited in Oakley *et al*., 1998). Maize technology generation alone is usually insufficient for sustainably raising agricultural productivity without complementary policy, institutional and infrastructural development (Byerlee and Heisey, 1996).

Institutions determine the users' choices affecting the process of learning and the cognitive models in a society to decide on what to choose from what is available (Bastiaensen *et al*., 2004). Evaluating the Sasakawa Global 2000's venture, Takele (1998) reported a significant improvement in maize technology adoption as a result of an informal person-to-person linkage among personnel working in stakeholder organizations signifying that formal and established linkages, partnerships and collaboration are essential components for an effective and efficient system of maize innovation.

2.3. Livestock Feed Resources in Ethiopia: Status and the Way Forward

Grazing is the predominant form of ruminant feeding system in most parts of the extensive and smallholder crop-livestock farming areas in Ethiopia. However, natural pasture as a source of feed is restricted to the wet season (Zinash *et al*., 1995). The major feed resources in the highlands are natural pasture, crop residues and stubble grazing (Alemayehu, 2004). Feed shortage has been understood as one of the most critical problems limiting livestock production and productivity. Substantial efforts have been made so far to resolve the feed shortage problem in the Ethiopian highlands, aiming at improving feed availability and thereby improve livestock productivity. However, the impact was so little to cope up with the problem that animals are still subjected to long periods of nutritional stress (EARO, 2001b). Studies have indicated that in Ethiopia, there is a feed deficit of about 12,300,000 tons of dry matter per year (Alemayehu, 2004). The adoption of feed technologies by farmers has been constrained by lack of follow up and technical backstopping (EEA/EEPRI, 2006).

Crop residues are important feed resources in the mixed crop/livestock production system. Reports (Daniel, 1988; Lemma, 2002) indicate that the contribution of crop residues to the annual livestock feed requirement reaches 40 to 50%. With the decline in the size of the grazing land and degradation through overgrazing and the expansion of arable cropping, crop residues have become increasingly important in the production system. According to EARO (2001b), about 14 million tons of crop residues are produced annually, cereal straws accounts for 95 % of the total crop residues while legume residues account for the rest. Among crop residues, teff straw, maize stover and sorghum stover constitute the bulk with contributions of 27, 27 and 22 % of the total residue yield respectively (EARO, 2001b).

In view of the existing scenario of the Ethiopian agriculture which is characterized by an ever declining per capita landholding (Byerlee *et al.*, 2007) and dwindling/deteriorating grazing areas, cereal based intensification is the future (Diao and Prrat, 2007). This calls for greater integration of crop (cereal) and livestock systems ensuring better and sustainable resource flows between the two enterprises. However, the contribution of the livestock sub-sector to crop production has been severely constrained by shortage of feed both in quantity and quality. As the level of dependence of livestock feeding on crop residues increases in the process, increasing the yield and quality of crop residues plays a pivotal role.

The yield and quality characteristics of residues are determined by the genetic makeup of the crop, growing conditions and harvesting, threshing and storage methods. The contribution of genetic as opposed to non-genetic factors to grain and fodder yields and to straw digestibility varies between crop species and among genotypes within a crop species. Varietal differences for crop residue quality have been reported in wheat, rice, sorghum and maize (Reddy *et al*., 2003). A report by Adugna (2002) revealed the possibility of selecting/breeding for maize varieties that combine high grain yield with desirable stover characteristics for livestock feeding in Ethiopia. If maize varieties that are with desirable fodder characteristics in addition to grain yield are generated and successfully adopted by farmers and become innovations, they will have an immense contribution towards achieving livelihood targets through enabling integrated and sustainable maize-livestock systems. A technology to become an innovation has to pass through a complex set of processes – the innovation system- in addition to the demand. As indicated in section 2.2, despite past research and extension efforts, the adoption of maize technologies has been poor. Therefore, analysis of the system using an innovation systems perspective is a crucial step to identify existing/potential problems and recommend possible remedies to enable maize-livestock innovation.

2.4. Crop-Livestock Integration: Challenges and Opportunities for Sustainable Agriculture

Over two-thirds of world's 1.3 billion impoverished people live in rural areas and rely on agriculture for a significant part of their livelihoods (Reddy *et al*., 2003). Livestock are important assets of this group and play a critical role in both sustainability and intensification of agricultural productivity in most farming systems. Increasing human population and changes in dietary habits associated with urbanization and higher incomes are causing increased demands for foods of animal origin. Delgado *et al.* (1999) estimated that between 1993 and 2020, the demand for livestock products will double and meat and milk production in developing countries will grow at annual rates of 2.7 and 3.2 %, respectively. The inability of farmers to feed animals adequately throughout the year continues to be the major technical constraint in meeting future demands for meat and milk. Improving the feed supply, both in yield and quality, is an effective means to build assets and increase livestock productivity.

Recurrent droughts that hit African Sahelian countries have been threatening the traditional practices of transhumant production systems. The combined effects of recurrent droughts and declining pasture availability have both resulted in major changes in livestock ownership and production systems pushing pastoralists to settle in cropping zones growing cereal staple food grains. The rise in human population and livestock numbers, decline in pasture availability and the expansion of cultivated areas have greatly increased the pressure on available land resources and led to declining soil fertility. With intensification of crop-livestock systems in sub-Saharan Africa, the quantity and quality of feed resources has decreased through the loss of communal grazing areas and increased pressure on arable land for food production. Livestock graze largely poor quality grasses or are fed low quality crop residues, for example, maize stover and barley straw (Delve *et al.*, 2001).

The above factors have inevitably accelerated the process of integrating livestock into crop production, as crop residues and manure are becoming increasingly valuable, the former for animal feed and the latter as fertilizer. However, the challenge of assuring the sustainability of the integrated farming system is how to integrate animal production with crop production so that it contributes to an intensification of both food production and cash income and encourages the maintenance of soil fertility.

As population density increases and less land becomes available, there is a general trend for crop and livestock activities to integrate. Livestock, and particularly ruminants, will continue to play key roles in providing draught power, manure to maintain soil fertility, animal food products, and opportunities for increased income generation. It seems likely that in much of the developing world, there will be an emphasis on milk production in crop–livestock systems involving ruminants, largely because of milk's ability to generate daily income for the smallholder household. If productivity is to increase because of increasing demand and increasing land pressure, then there are real research needs to enhance the complementarities between crop and livestock production.

Increasing the linkage between crop and livestock production is an effective means by which plant nutrients can be rapidly recycled within and between farms. On the other hand, the factors driving intensification often lead to the expansion of cropped areas and more intensive cropping practices at the expense of grazing land. In the face of declining grazing land the potential of arable land to provide fodder throughout the year must be enhanced, if the important role of livestock within the farming system for household welfare is to be maintained or developed.

Sustainability has been defined as meeting the needs of the present without compromising the ability of future generations to meet their own needs (Bishop, 1993 as cited by Vavra, 1996). In livestock production, sustainability can mean being able to harvest the same quantity of meat or fiber from a given land base indefinitely. In other words, the offtake of products (meat or fiber) does not decay the ability of the land-base to continue providing the materials (e.g., forage) for further offtake (Vavra, 1996). This phenomenon, though it may seem very ambitious, could be achieved by maintaining continuous and positive nutrient cycling between livestock and the land in a system as depicted in Figure 2. In this case efficient use of crop residues for livestock feeding plays a significant role.

According to Sumberg (2003), the most common forms of integration - including herder–farmer exchanges of grain, milk and manure, crop residue grazing and animal traction - have been studied from technical, economic and social perspectives, and are recognized as critical to the functioning of certain production, livelihood and social systems. Mixed crop-livestock production system in Ethiopia has a long evolutionary history as sedentary agriculture. Currently, this is the most dominant land use system where the largest share of both crop and livestock products are derived (CSA, 2006). The potential of the system for achieving food self-sufficiency and establishing reliable material supply for industrial processes is immense provided that a sustainable balance among the different components of the system is maintained. The greatest potential for the use of crop residues as animal feeds exists in the mixed crop-livestock systems of the semiarid and sub-humid tropics. The demographic and economic changes expected in Ethiopia will reinforce the importance of crop residues as animal feeds. Increased production of residues through varietal selection and breeding and following different agronomic practices of crops and the efficient use of them by utilizing recommended strategies of feeding will enhance crop-livestock integration and then sustainable socioeconomic development.

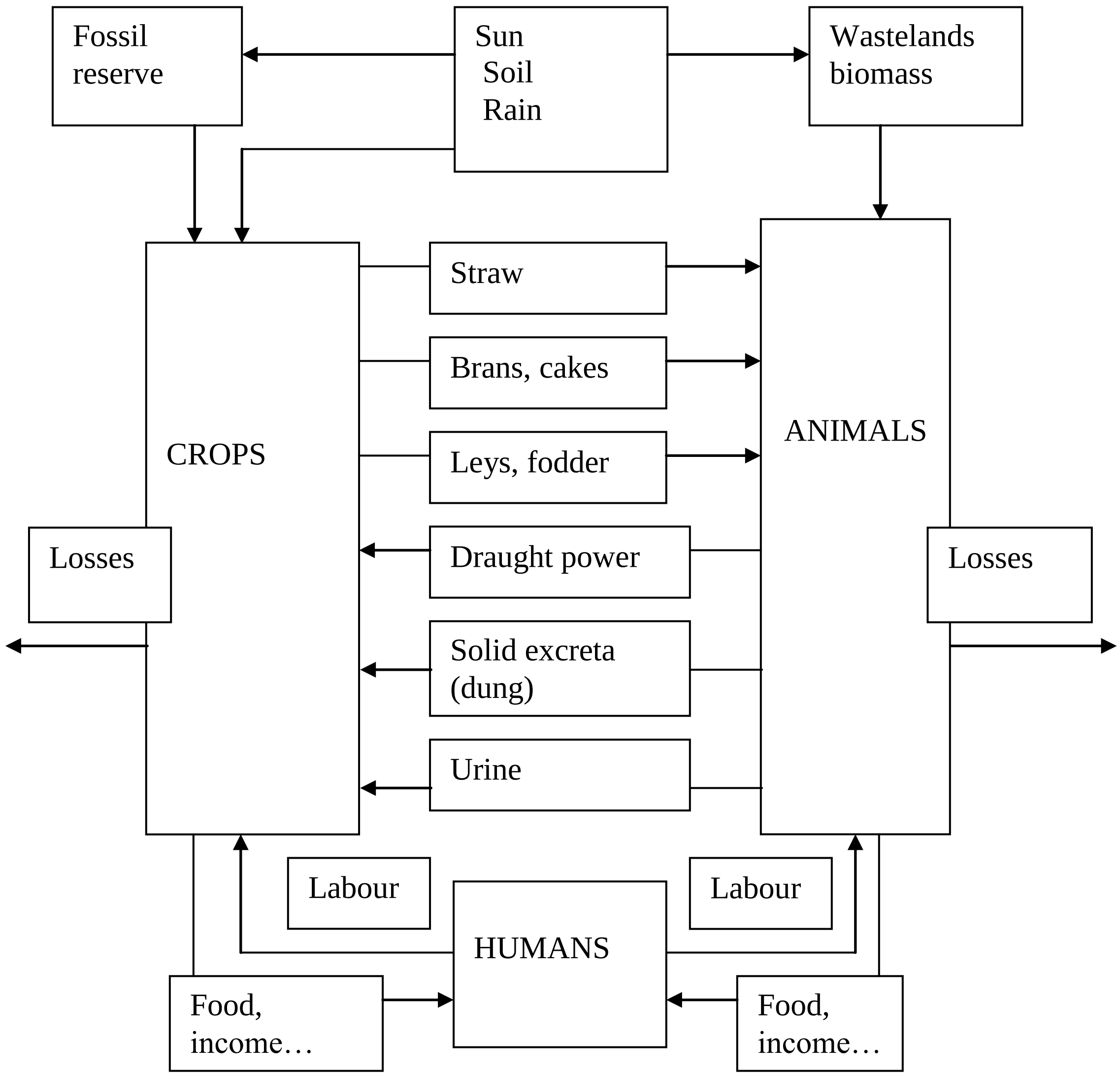

Figure 2. Schematic representation of resource flows in a mixed crop-livestock system (adapted from Schiere *et al*., 2006).

Agricultural intensification through crop and livestock integration is the future of agricultural development in Ethiopia (Byerlee *et al.*, 2007; Diao and Prrat, 2007). Research packages should aim at maximizing output per unit area of land. This would be achieved by the generation and productive use of agricultural technologies and knowledge with multiple uses and a better rate of uptake by the end users. This requires a multidisciplinary approach taking into consideration the farming circumstances along with new ways of institutional, policy and learning processes by involving a wide array of stakeholders – professionals of diverse specialties, policy makers, farmers, NGOs, community-based organizations, etc. with a common understanding and focus on sustainably improving the performance of the agricultural sector.

The growing importance of maize and livestock to Ethiopia's socio-economic development process has been underlined by a number of analysts. Despite this fact, there is a persistent concern that technological advances related to increased maize production and livestock productivity have not been integrated to the extent they could, particularly not well enough to enable developing countries like Ethiopia to deal with the challenges associated with high population growth rates and the subsequent pressure on land and feed resources. Adoption of improved fodder varieties remains low. This research took an innovation systems perspective to explore the level of integration between the maize and livestock sectors and explain why the desired level of integration and adoption has not occurred to the extent it could.

2.5. Concepts of Innovation Systems and the Maize-Livestock Innovation System

The current body of literature (Mytelka, 2000; Carlsson *et al*., 2002; Hall *et al*., 2006) defines an innovation system as a network of organizations, enterprises, and individuals focused on bringing new products, processes, and new forms of organization into economic use, together with the institutions and policies that affect their behavior and performance. The innovation systems concept embraces not only the science suppliers but the totality and interaction of actors involved in innovation. Innovation encompasses the factors affecting demand for and use of knowledge in novel and useful way. Novelty – the process of creating local change, new to the user is fundamental to innovation (World Bank, 2006). A more generic form of the innovation systems perspective known as 'National Innovation System' (NIS) aims at highlighting the importance of interactions between all entities involved in the system (Speirs *et al*., 2008) and the other form known as 'intervention based innovation system' focuses attention on issues relevant to a specific intervention.

According to Mytelka (2000), innovation is the process by which organizations "master and implement the design and production of goods and services that are new to them irrespective of whether they are new to their competitors, their country or the world". Innovations are new creations of social and economic significance; involve a combination of technical, institutional and other sorts of changes (World Bank, 2006). Innovation is a non-linear process of learning (Mytelka and Smith, 2002).

The proposed research shall consider a highly integrated, mixed crop–livestock farming system to be one that produces both crops and livestock simultaneously using resources from within the same, relatively small geographical area. The crop and livestock assets are owned and managed by a single individual or by a household or other tightly knit group. There are positive flows of plant biomass, manure, power and financial resources between the crop and livestock activities, and these flows support increases in efficiency, productivity and sustainability.

A working definition of the maize-livestock innovation system can be the process of using newly generated or already existing knowledge and associated services in productive ways (for market and non-market functions) by farmers that produce in the mixed maize-livestock production system. It is constituted by overlapping flows of knowledge and relationships across a diverse set of actors in the maize and livestock sectors - together with the underlying institutions and policies - whose combined effectiveness helps define the extent to which new products, processes, and new forms of organization are translated into social and economic use. In this context, innovation systems concept focuses attention on the broad range of players involved in the process of innovation – farmers, scientists, traders, development workers, policy makers, the livestock dependant poor, etc. It recognizes that innovation and the creation of novelty takes place through the interaction of these players and the process of knowledge sharing and learning that this interaction allows. The capacity to innovate and use knowledge productively is therefore a function of patterns of interaction and the factors that shape these interactions – usually the habits and practices (or institutions in the sense of norms and rules) that shape the behaviour of different players (World Bank, 2006).

The innovation systems concept emerged as a response to the limited explanatory power of conventional economic models that view innovation as a linear process driven by the supply of research and development (Hall *et al.*, 2006). The framework is now being used to understand and strengthen innovation at national and sector levels. Innovation systems are very important determinants of technological change. Traditional methods of innovation that mainly focus on the structure of innovation systems have proven to be insufficient (Hekkert *et al*., 2007). This state of insufficiency has resulted in the development of new techniques of evaluating innovation systems focusing on a number of processes that are important for well performing innovation systems. Innovation creates new opportunities, these opportunities may not be realized or converted into economic activity until the prerequisite inputs (resources and skills) and product markets are in place (Carlsson *et al*., 2002).

The innovation system is more inclusive than the relatively narrow notion of a research system. The research system is a system of public sector organizations/actors engaged in generating knowledge and technologies. The extension system, made predominantly of public sector actors, is responsible for the adaptation and diffusion of the technologies. In contrast, the innovation system encompasses all components of the system of public, private, voluntary or other organizations/actors whose interactions and networking processes produce, diffuse and use economically useful knowledge. In contrast to the research system that generates technological innovations, the innovation system produces technological and institutional innovations. In an innovation system both technological and institutional innovations are generated, modified, sustained and utilized. Raina (2003) discussed that features of successful innovation systems are: continuous evolutionary cycles of learning and innovation; combinations of technical and institutional innovations; interaction of diverse research and non-research actors; shifting roles for information producers, information users and a need based exchange of knowledge; and an institutional context that supports interactions and knowledge flows between actors.

This study stems from a hypothetical view that non-adoption of maize technologies is a result of the relative capacity of the maize innovation system and its sensitivity to the circumstances of the farmers, markets, and the environment (policy and institutional) associated with the maize value chain. Analyzing the maize-livestock production system using the innovation systems framework will have a significant contribution to make the system more productive and sustainable by indicating potential policy, research and development interventions at micro, *meso* and macro levels. This type of work indicates directions on what has to be done in order to make the maize-livestock innovation system continuous through the integration of maize and livestock production aiming at sustainable socioeconomic development.

Hypotheses:

1. There is no varietal difference in the yield and quality of maize stover.
2. Maize variety preference by farmers is not affected by socioeconomic nor institutional nor technological factors.

Research questions: This study was conducted to answer the following sets of research questions:

1. What are the feed resources and how are the feeding systems (with particular emphasis on maize stover) in the study areas? What are the farmers' perceptions about the feed values of existing maize varieties? Is there an actual demand for dual purpose (food-feed) maize varieties? Do variations in variety and stage of grain maturity at harvest affect the yield and quality of maize stover?
2. What are the constraints limiting functional linkages between the maize and the livestock subsystems?
3. What socioeconomic, institutional and technological factors influence household decision on what improved maize variety to adopt?
4. How does the maize-livestock innovation system operate? Is there an enabling environment for a successful maize-livestock innovation? What are the possible interventions to enable a successful maize-livestock innovation system? What does the maize value chain look like?

3. MATERIALS AND METHODS

3.1. Description of the Study Sites

Three study areas with possibly contrasting demands for maize as food-feed crop, and therefore variety selection criteria, were identified by combining and overlaying maps and information from CIMMYT, IFPRI and ILRI. In the process of selecting the study sites, information related to maize cropping areas and mega environments, human population densities, livestock systems and livestock numbers were synthesized using GIS. The identified sites were Awassa, Bako and Ambo areas from which Awassa, Bako Tibe and Ambo districts were selected for the household level study. All the data used to describe the study districts were collected from unpublished sources from the respective district offices of agriculture and rural development in 2008.

The Awassa area is characterized by significant use of maize fodder as animal feed**.** The area has high population densities for both cattle and humans; low availability of other crops providing feed and limited area for grazing because of the high human population density. Inhabited by ethnic Sidama, Awassa district is found in the Southern Nations, Nationalities and Peoples Regional State in the west of Awassa town bordering Lake Awassa. It is a mid-altitude moist ecology dominated by highly drained sandy loam soil situated at the base of the rift valley system some 275 km south of Addis Ababa. It is a plain bottomland. The human population size is 92658 heads and 16932 farm households. It has about 124329, 14587 and 22182 heads of cattle, sheep and goats, respectively, among the ruminant livestock species. Maize, haricot bean, and enset (*Ensete ventricosum*) or false banana are the dominant crops grown in the area. It receives 1322 mm annual rainfall and the elevation ranges from 1684 m to 2729 m above sea level. .

In the Bako area there is little use of maize fodder. The area has low populations of both cattle and humans and therefore it was expected that there is significant land available for grazing. Hence, although there is low availability of other crops providing feed, it was expected that maize would not contribute significantly to feeding livestock. Field visits confirmed this was the case – maize being left standing with uncontrolled grazing by livestock following harvest. Located at 250 km west of Addis Ababa in the Oromiya Regional State, Bako Tibe district represents one of the highest maize growing areas of the country positioned in mid-altitude humid ecology. The soil type is dominated by red loamy soil.. The human population is 125130 with a farming household size of 18444. It has 121757 heads of cattle, 10993 sheep and 12418 goats. The dominant crops grown in the district include maize, sorghum and teff. The area receives an average rainfall of 1101 mm per annum and the elevation ranges from 1568 m to 2604 m above sea level.

The Ambo area is characterized by little use of maize fodder. This area has human and cattle population densities similar to that of Awassa. However, other crops providing feeds are also available and field visits confirmed that use of maize stover for livestock feeding is not common. Ambo district is located 125 km west of Addis Ababa in the Oromiya Regional State. Its topography is characteristic of rugged type terrain with mountains and gorges. It is among the humid ecologies and the soil types are mixed – red and vertisol. The human population is estimated at 147367 with 21072 farm households. The major crops grown in the district include teff, wheat, barley, maize and sorghum. The district is inhabited by 112236 heads of cattle, 24966 sheep and 16399 goats. It receives an annual rainfall of 1143 mm with an elevation ranging from 1342 m to 3229 m above sea level. The map of the study districts is presented in Figure 3.

3.2. Study Design

The study involved three levels of analysis: the micro, *meso* and macro. The micro level mainly focused on the identification and analysis of factors that shape household decision making with regard to the choice of maize varieties for adoption. The *meso* and macro levels encompassed community (districts) and national level case studies, respectively.

3.3. Sample Size and Method of Sampling

In line with the study design, the site and household selection processes covered the case study areas and households in order to address the micro and the *meso* level objectives. The macro level study followed purposive selection of the key actors and institutions based on secondary sources of information and informal assessments. Three case study districts were purposively selected from each study area based on their maize area coverage that included nine districts in total. These were Wondogenet, Awassa, and Boricha districts from the Awassa area; Gobbu Sayyo, Sibu Sire and Bako Tibe districts from the Bako area; and Ambo, Tokkie Kuttaye and Dendi districts from the Ambo area. The *meso* level study covered all the nine districts in the three case study areas. For the household level study, however, one district was randomly selected from each of the three case study districts per site/area. The selected districts were Awassa, Bako Tibe and Ambo and six peasant associations were randomly selected from each district. The total sample size for the household based survey was set to be 350. The number of sample households per district was determined based on the principle of 'probability proportional to size'. As indicated in Section 3.1, the numbers of farm households were 16932 in Awassa, 18444 in Bako Tibe and 21072 in Ambo. Accordingly, 90, 120 and 140 sample households were randomly selected and contacted from Awassa, Bako Tibe and Ambo districts, respectively.

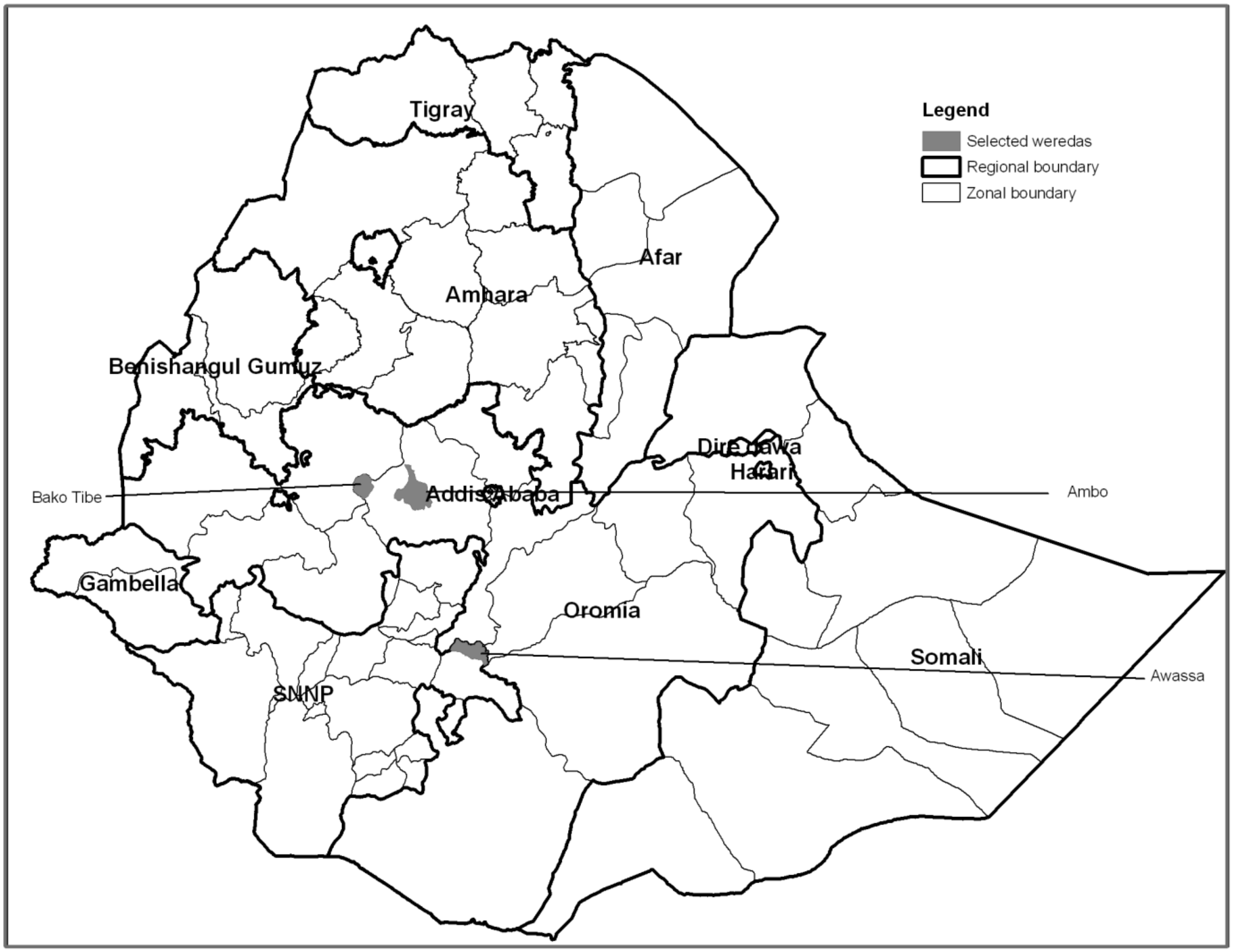

Figure 3. Map of the study districts.

3.4. Methods of Data Collection and Analysis

The study involved collection and analyses of both primary and secondary data. The primary data were collected through focus group discussions, key informant interviews and household level surveys. Focus group discussions and key informant interviews were conducted between August and November 2007 whereas the household level surveys were carried out in March, April and May of the year 2008. The methods of data collection and analyses employed at each of the levels according to the study design are described in the following sub-sections.

3.4.1. The macro level

The macro level focused mainly on characterizing the maize-livestock innovation system from a national perspective. Key actors involved in the maize-livestock innovation system were identified utilizing secondary literature and key informant interviews at a national level. The role (s) of the actors, interactions and linkages to others in the process were documented. The traditional habits and practices of the actors with regard to learning, linkages and investment, and their competencies and performances were assessed. Analysis of the system at a national level included interviewing researchers and extension personnel at university and college centers, and national, regional and international agricultural research organizations on the extent of their collaboration and linkages, and on how research priorities emerge using guidelines. Relevant policy documents were reviewed and their implications to the performance of the maize-livestock innovation system analyzed along with analysis of the institutional arrangements that influence the behaviour of actors in the innovation system.

3.4.2. The *meso* level

The maize – livestock innovation systems in the case study areas were characterized following similar procedures as the macro level. At this level due consideration was given to the analysis of trends and practices in crop and livestock production, with a special emphasis on feeding systems through focus group discussions and key informant interviews. Livestock feeding systems and feed resources of the study areas were assessed. Farmers' ratings about the fodder value of the maize varieties they experienced were assessed by visiting the farms during the growing season along with monitoring on-farm feeding practices through informal group discussions and ranking exercises (pair-wise ranking) involving livestock owning groups. Farmers’ evaluation of the maize varieties as feed was explained by corresponding data on the yield and quality of stover from different maize varieties.

3.4.2.1. Stover sampling and analysis

Stover sampling was done at two stages of grain maturity: green (*eshet*) and mature (dry) stages with the objective of determining the effect of stage of maturity at harvest and variety on the yield and quality of maize stover. The mature stage sampling was done at the time of grain harvest. A total of 16 varieties were considered where the actual number of varieties at each of the stages was 15 omitting one variety (Pioneer) at the green (*eshet*) and another (*Sidancho*) at the mature (dry) stage due to some inconveniences during the process of sampling. Sampling Pioneer at the green stage was not possible because the available plots were under another observation at that stage and the household where the green stage of the *Sidancho* variety was sampled finished it at the green (*eshet*) stage. The list of varieties and the sites and stage of maturity at sampling are shown in Table 2. For those varieties common to Awassa and Bako, site means were considered as replicates. Except for the landraces, sampling was done from on-farm demonstration plots at Awassa, Bako and Kulumsa by cutting on average 10 randomly selected maize plants from a plot and the conversion of yield per ha was according to the planting density. Samples from the landraces were collected from farmers' fields in Awassa and Bako where they were grown under different management conditions as compared to the other varieties. The landraces were broadcast on fields around the homesteads where they usually receive manure. Though this was the situation, landraces were included in the analysis to serve as references. The dry stage sampling included partitioning of the total biomass into grain, stover and cob. Sub-samples of 200g – 400g were taken in two replicates after mixing (homogenization) of the bulked fresh samples for further analysis.

Table 2. List of varieties and the sites and stage of maturity at sampling.

Variety	Site			Stage of maturity	
	Awassa	Bako	Kulumsa	Green/Eshet	Mature/Dry
BH543[a]	x	x		x	x
BH542[a]	x	x		x	x
BH545[a]	x	x		x	x
BH540[a]	x	x		x	x
BH670[a]	x	x		x	x
BH660[a]	x	x		x	x
Sidancho[c]	x			x	
Kuleni[b]		x		x	x
Gibe 1[b]		x		x	x
Gutto LMS5[b]		x		x	x
BH140[a]		x		x	x
Burre[c]		x		x	x
Arganne[a]			x	x	x
Wenchi[a]			x	x	x
Jibata[a]			x	x	x
Pioneer[a]	x				x

[a] Hybrid variety (a maize variety produced from a cross between two or more inbred lines with different genetic constituents under controlled pollination).

[b] Open pollinated variety - OPV (a variety that has been grown and selected for its desirable traits under natural pollination).

[c] Local variety (Landrace).

The fresh stover samples were oven dried at 60^0C for 48 hours and ground to 2 mm size. The chemical composition - ash, nitrogen, neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) and nutritive values – *invitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) values of the stover samples were estimated using the near infrared reflectance spectroscopy (NIRS) technique (Windham *et al.*,

1989) at ILRI-Ethiopia. The crude protein (CP) contents were determined by multiplying the nitrogen contents by 6.25. The hemicelullose and cellulose contents were also computed from NDF, ADF and ADL values as hemicellulose = NDF – ADF and cellulose = ADF – ADL. Moreover, digestible stover dry matter contents were determined as a product of stover dry matter yield and the respective IVOMD coefficient. Analysis of variance (one way using SPSS version 15.0 software) was carried out to see variety effects on the measured variables and mean separation was done according to the Duncan's multiple range test procedure. Correlation coefficients were computed to see the relationship between stage of maturity at harvest and grain yield with measured stover yield and quality parameters.

3.4.2.2 Procedures and description of the NIRS technique used

The analysis of the stover samples using the NIRS technique was conducted as a subset of a large number of maize stover samples collected from Tanzania and Ethiopia. The samples were scanned in spinning sample cells (ISI, Part number IH-0307) at 2 nm intervals for their measurements, such as inverse of the reflectance (log 1/R) over the NIR spectral range from 1100 to 2498 nm in reflectance mode by using a spectrophotometer model Foss 5000 (Foss NIR Systems, Silver Spring, MD, USA) and the chemometrics software WinISI II (Infrasoft International, LLC, 109 Sellers lane, PA 16870, USA) version 1.50 was used. In order to highlight the chemical entities, the noise from spectral distortions was reduced by the use of standard normal variance (SNV) and de-trending (DT) transformation (Barnes *et al*., 1989).

The NIRS global calibration equation for maize samples was selected (NIRS models) to predict the unknown samples set and taken the blind predicted results in to considerations. The calibration samples were selected by the spectral selection procedures for crop and experiment specific product calibration equations. All the samples were pooled for arriving at an expanded global calibration equation for the samples. The expanded maize global calibration samples were split in to two equal sets of 50% each and the first set was termed as calibration set and was used for calibration and the remaining set was used for validating samples testing the calibration equations' robustness and precision. The problems with strong dependence between spectral signals in different wavelength bands were avoided by the reduction to a few latent orthogonal variables (terms) using the modified partial least squares regression by Shenk and Westerhaus (1991). The optimal number of terms to be included in the NIRS models was determined as having the lowest standard error of cross validation (SECV) (Windham *et al.*, 1989). For more information please look at Table 1 of the Appendix.

3.4.3. The micro level

This level has the principal aim of identifying factors that influence maize variety preferences at a household level. Data were generated using a structured questionnaire through face-to-face individual interviews between trained enumerators and farmers where farmers were asked to express, among others, their preference to available set of maize varieties. This was done under close supervision by the principal investigator. The data were subjected to regression analysis where farmers' maize variety preference was used as the dependent variable. Descriptive statistics was also employed as a tool for data analysis.

3.4.3.1. The analytical framework

The decision whether or not to use a technology could be considered under the general framework of utility or profit maximization (Pryanishnikov and Katarina, 2003). It is assumed that economic agents, including subsistence smallholder farmers, use a technology only when the perceived utility or net benefit from using a technology is significantly greater than would be the case without the technology (Chilot and Hassan, 2008). While utility is not directly observed, the actions of economic agents are observed through the choices they make. Therefore, it was assumed that farmers in the study areas choose a particular variety when the net benefit they get from the variety exceeds that from other varieties.

The utility derived from the j^th variety can be modeled as a latent variable, which is a linear function of a vector of attributes which characterize the i^th household (Z_i) and attributes that characterize the j^th variety (X_j) i.e.,

$$U_{ij} = X^{'}_{ij}\beta + Z^{'}_{i}\gamma_{j} + \varepsilon_{j},\ where(\varepsilon_{j} \sim N(0,\sigma^{2})\ j = 1, 2, ...m.$$

where β represents parameters to be estimated and ε_j the disturbance term. The disturbance terms are assumed to be independently and identically distributed. If the farmer's choice is variety j, this implies that:

$$\Pr(U_{ij} > U_{ik},)\ \ \forall k \neq j_{.} \qquad (2)$$

Where U_{ij}, is the utility to the i^th individual of variety j, and U_{ik} is the utility of variety k to the i^th household. If each arrangement is considered as a possible decision choice by the farmer, the decision maker is expected to choose that variety which will maximize the perceived utility. Therefore, given finite set of varieties to select from, the decision of the i^th household can be modeled as maximizing the utility of streams of net benefits by picking the j^th alternative from among the J discrete choices available such that:

$$Max_{j}\{E(U_{ij}) = f_{j}(X_{ij}) + g_{i}(Z_{i}) + \varepsilon_{ij}\}$$

Where f_j *is a function of* $X_{ij} = (X_{i1}......, X_{in})$, and g_i is a function of $Z_i = Z_1,..Z_n,$ of attributes of the j^th variety and i^th household, respectively, that are expected to potentially affect the desirability of a variety.

In the study areas, there have been a set of maize varieties to choose from. Assuming that a household can identify the most preferred variety, a multinomial logit econometric technique can be used in the empirical investigation of the factors associated with the decision of the households.

Since U_{ij} is latent, it is not observable. Therefore, let Y_{ij} be the indicator variable, so that:

$$\Pr(Y_{ij} = j) = \frac{\exp(X_{ij}^{'}\beta + Z_i^{'}\gamma_j)}{\sum_{l=1}^{m}\exp(X_{il}^{'}\beta + Z_i^{'}\gamma_l)}, \quad j = 1, ..., m. \tag{3}$$

Where $\Pr(.)$ is the probability that the i[th] individual chooses the j[th] variety. X_{ij} represents a vector of demographic, economic and spatial characteristics for the observed individual households. β and γ are coefficients to be estimated. This is a specification that includes explanatory variables that vary over alternatives (X_{ij}) and those which do not vary over alternatives (Z_i). This specification is referred to as mixed logit (Cameron and Trivedi, 2005).

The log-likelihood function for the mixed logit model is given by:

$$\ln L = \sum_{i=1}^{n}\sum_{j=0}^{J} d_{ij} \ln \frac{\exp(X_{ij}^{'}\beta + Z_i^{'}\gamma_j)}{\sum_{l=1}^{m}\exp(X_{il}^{'}\beta + Z_i^{'}\gamma_l)} \tag{4}$$

Where d_{ij}=1 if individual i chooses alternative j and d_{ij}=0 otherwise (Greene, 2003; Han and Harrison, 2004).

3.4.3.2. Variables and hypotheses

There have been numerous reports on factors that influence agricultural technology adoption. Therefore, the factors hypothesized to influence farmers' maize variety preference (the dependent variable) were selected based on available literature. The factors (explanatory variables) considered were farmer characteristics, institutional factors and the variety attribute. The farmer characteristics included total farm size owned, livestock ownership, family size, education level of the household head and farming experience of the household head. The institutional factors, on the other hand, included access to credit, market and extension services. The variety attribute considered was 'potential utility index' which takes into account both grain and feed (stover quality and quantity) related attributes.

During the selection of the explanatory variables, this research has heavily drawn information from the work of Tesfaye *et al*. (2001) on determinants of adoption of improved maize varieties in major maize growing regions of Ethiopia. These authors reported positive and significant influence of family size, livestock ownership and distance to the nearest market center on improved maize variety adoption. However, Berhanu *et al*. (2007a) reported a negative influence of distance to the nearest market center on maize variety adoption which is in complete agreement with the logic that farmers located far from market centers will be less likely to be adopters of a technology.

The variables hypothesized to influence maize variety preference in this study are described as follows:

Location (LOC): This variable indicates where a farmer resides. Location variation is highly related with variations in the physical environment (agro-ecology) and access to information and resource which in turn affects the type of maize variety to be grown and farmers' preference of maize varieties.

Family size (FAMSZ): This variable refers to the total number of people who are members of the household in question. This is expected to influence variety preferences by affecting labor available for farm activities. Different maize varieties require different management practices, the successful practice of which depends on the household's labour endowment.

Total farm size (FARMSZ): This represents the total cultivable land owned (ha) by a household. This variable is expected to negatively influence the household's decision to use improved maize varieties with better fodder value since households with relatively large cultivable land will have the inclination to leave a portion of their land for grazing and therefore, have less need of stover for fodder.

Education level of the household head (EDU): This variable refers to the grade or years of formal schooling that the household head attended. Higher educational level is believed to be associated with the ability of obtaining, processing and utilizing new information, suggesting households with higher level of education would be more likely to adopt new technology.

Farming experience (FRMEXP): This is the number of years that a farmer experienced farming on his own. Short planning horizons in this study are equated with older but more experienced farmers who may be reluctant to switch from traditional methods to new practices because of their accumulated experiences whereas younger farmers with longer planning horizons may be more likely to take up new opportunities (Chilot and Hassan, 2008).

Livestock ownership (LVSTK): This variable refers to the total number of tropical livestock units (TLU) that a household owns. As the level of livestock ownership increases, the strength of the household to adopt new technologies becomes stronger. Moreover, livestock ownership is expected to positively influence the preference to maize varieties that can supply good fodder quality and quantity. In this study, livestock ownership is confined to cattle, small ruminants and equines as these are the species to which maize stover is and could be fed (the conversion of animal numbers into TLU is as per (Gryseels, 1988)).

Access to credit (CRDIT): It is a dummy variable taking a value 1 if the household head reported that he/she has an access to credit and 0 otherwise. Access to credit for agricultural purposes can relax farmers' financial constraints and is expected to increase the probability of being involved in technology adoption. This is expected to influence varietal preference in connection to the level of input requirement associated with a particular choice.

Access to extension services (DISEXT): Refers to the walking distance to the nearest development center measured in minutes. This variable accounts for the time a farmer may need to walk to contact his/her extension agent. The farther an extension office is located from farmers' homes, the less likely it is that farmers will have access to information and then make informed choices. Several studies show that farmers' contact with extension increased the probability of adoption and area allocation to improved maize varieties (Getahun *et al.*, 2000; Abdissa *et al.*, 2001). Based on these grounds, farmers' contact with extension workers is hypothesized to increase their likelihood of adopting improved maize varieties.

Access to market (DISMRKT): This variable refers to the walking time required to reach the nearest market center, which was expressed in minutes. The longer the walking time to markets, the lesser will be the likelihood of the household head to adopt new technology. Access to market is an important factor that affects farmers' inclination towards commercialized (market-oriented) production in terms of ease of procuring inputs and selling output. This in turn, influences farmers' choice of a variety and scale of production. If a farmer is far away from the market, it may be difficult for him/her to get improved farm input technologies or sell increased output from growing improved varieties. The study by Shiferaw and Tesfaye (2006) indicated that access to market is negatively related to the probability of growing improved maize varieties.

Potential utility index (PUI): Farmers have subjective preferences for technology characteristics and these could play major roles in technology adoption. Adoption or rejection of technologies by farmers may reflect decision making based upon farmers' perceptions of the appropriateness (inappropriateness) of the characteristics of the technologies under investigation (Adesina and Zinnah, 1993). Guided by the maize breeding programs which basically aimed at improving grain yield without concern for yield and quality of the stover, variety attribute issues so far have been literally confined to grain yield whenever considered. However, realizing the contribution of maize stover for livestock feeding in the mixed crop – livestock production system of the major maize growing areas of the country, it was hypothesized that both grain yield and feed related attributes of maize varieties influence farmers' decisions or preferences for adoption. Therefore, potential utility index (PUI) was considered as one of the explanatory variables as a variety attribute expected to influence variety preference. Potential utility indices of the varieties were computed according to Adugna, *et al*. (1999) employing the formula:

$$\text{Potential Utility Index (PUI)} = \frac{Grain\ yield + Digestible\ stover\ dry\ matter\ yield}{Total\ above\ ground\ biomass\ yield} \times 100$$

Because of the difference in the set of maize varieties available for choice in Ambo, Bako and Awassa areas, the analysis excluded the Ambo data. Some farmers failed to state their preference by name of the variety and these were also excluded. Therefore, the total sample size for this analysis was 181. Moreover, during the initial steps of the analysis, walking distance to the nearest market center and distance to development center were found highly correlated and thus distance to the nearest market was omitted. The model was also corrected for the presence of heteroscedasticity using White's heteroscedasticity correction standard error (Robust standard error). The dependent variable takes on three discrete values (1= BH660, 2= BH540 and 3= Pioneer), and BH540 was used as a reference category in the variety choice model.

4. RESULTS AND DISCUSSION

This chapter consists of four major sections. Theses include farmers' practices in the use of maize stover for livestock feeding and effects of variety on the yield and quality of the stover; analysis of constraints to the linkage between the maize and the livestock sub-systems; factors that affect farmers' choice of maize varieties; and characteristics of the maize-livestock innovation systems.

4.1. Farmers' Practices in the Use of Maize Stover for Livestock Feeding and Effect of Variety on the Yield and Quality of Maize Stover

4.1.1. Farmers' practices in the use of maize stover for livestock feeding

As it was common to most parts of the country, some 100 years back, the study areas were covered by forest which was full of wildlife. During those days, livestock rearing was the main way of life. The transformation of the lifestyles of human communities from complete livestock dependence to shifting cultivation and hoe culture which started by growing some cereals out of their wild forms was slow. Dependence on livestock production was pushed away by the continuously declining land size per household and the subsequent feed shortage as a result of deforestation and degradation of communal grazing lands caused by ever increasing population pressure. Farmers believe that the shortage in feed has not only reduced production but has also limited the genetic potential of livestock, for example, the body size of cattle has become smaller. In almost all of the study districts, communal grazing lands are not available currently. Animals are kept standing on a bare field, like the one depicted in Figure 4, and given byproducts of cropping when they are back from the field or tethered around the homesteads (this is particularly true in the Awassa area) and fed on crop residues and/or weeds harvested from cropland. Shortage of feed is putting an immense pressure on farmers' practice of keeping livestock. Forced by the severity of feed shortage, farmers are trying to make livestock feed on every byproduct of the crops they grow.

Figure 4. Common type of grazing field in the Bako area.

Farmers in Ambo and Bako areas have more sources of crop byproducts than those in Awassa due to more diverse crops grown (Table 3). Maize fields supply much of the feed requirements of a household in the study areas. This agrees with Berhanu *et al*. (2007a) that an estimated 69% of livestock feed in the major maize growing areas of the country comes from maize production. Feed from maize production is collected during weeding, when thinning the infertile plants and tillers during blooming, during defoliation of the plants at the dough stage and the residue after grain harvest. Except in Awassa, dry maize stover is not collected and piled for use during times of more severe feed shortage. It is left to be consumed on the field immediately after grain harvest (Figure 5). Farmers believe that the practice of leaving the residue on the field is beneficial for restoring soil fertility through manure deposited by animals that graze the aftermath and the residue. However, because the exercise is done during the dry period, the nutrient losses through evaporation (of urine) and hardening (of solid excreta) for decomposition affect the contribution of the animal wastes to the soil.

Figure 5. System of feeding on maize residue in Bako and Ambo areas.

Table 3. Classification (%) of farmers by annual crops grown in 2007/2008 in the study districts.

	Crop												
District	Maize	Teff	Wheat	Sorghum	Grass pea	Barley	Niger	Chick pea	Field pea	Faba bean	Haricot	Potato	Pepper
Ambo (n = 140)	96	67	74	34	40	8	16	26	9	9	0	0	0
Bako Tibe (n = 120)	98	71	6	51	0	0	24	0	0	8	0	0	42
Awassa (n = 90)	98	0	0	0	0	0	0	0	0	0	12	8	15

n = number of respondents

Both improved and local varieties of maize are grown in all of the study areas. Table 4 shows the proportion of farmers who grew improved maize varieties in the 2007/2008 cropping season in the study districts. The intensity of using improved maize varieties was higher in Bako Tibe and Awassa districts than in Ambo district.

Though farmers do put priority to grain yield and other parameters (resistance to pests and diseases, resistance to lodging, etc.) that are directly linked with it, livestock owning ones do show interest to grow dual purpose maize varieties and were able to rate varieties they have experienced most in terms of feed value. Farmers' ratings of the varieties for biomass production and 'palatability' (acceptance/preference by animals and volume consumed from a given offer) are presented in Table 5. The variety with the name BH660 was rated best for biomass yield in Ambo and Bako areas whereas the local variety (*Burre*) least. In terms of palatability, the reverse was true. The local variety *Burre* was rated first in terms of palatability because of its sweet taste and ability of staying green for longer period of time. On the other hand, in Awassa, the variety with the name BH540 was rated best for biomass yield followed by Pioneer, and the local *Sidancho* was least. Similar to the cases in Ambo and Bako, the local variety *Sidancho* was rated best for its palatability. The local varieties were rated best for palatability mainly because of their softer stems but were characterized for being susceptible to lodging. The improved ones are with stronger stems which negatively affects the palatability of their stovers. This suggests that a breeding and selection strategy for maize genotypes with better feed value needs to focus, in addition to improving stover yield, on manipulating traits responsible for structural tissue development without compromising the merit for resistance to lodging. A high degree of structural tissue deposition limits the intake and digestibility of a feedstuff of plant origin since it is accompanied by a high rate of lignification of carbohydrates in structural tissues.

Table 4. Classification (%) of farmers by improved maize varieties grown in 2007/2008

Variety	District		
	Ambo (n=135)	Bako Tibe (n=118)	Awassa (n=88)
BH660	16.4	80.8	0
BH540	0	46.7	42.2
BH140	0	8.3	2.2
BH542	0	0	2.2
PH30HB83	0	7.5	22.2
Kuleni	12.1	0	0
Other	2.2	0	2.2

n = number of respondents.

Table 5. Farmers' rankings of maize varieties for feed value (stover yield and palatability) in the study areas listed in a descending order row wise.

District	Total stover yield	Palatability
Ambo	BH660, BH540, Local (*Burre*)*	Local (*Burre*), BH540, BH660
Bako	BH660, BH540, Local (*Burre*)	Local (*Burre*), BH540, BH660
Awassa	BH540, Pioneer, Local (*Sidancho*)	Local (*Sidancho*). Pioneer, BH540

* words in parenthesis and italics are names of local varieties (landraces)

All the sites face at least three months of severe feed shortage (Table 6). Reported months of most severe feed shortage are April – June in Ambo, March – May in Bako and February – April in Awassa. The differences over sites are attributed to ecological variation which is mainly attributed to rainfall regime. Farmers follow different feeding practices during times of severe feed shortage using feed resources such as conserved crop residues, tree leaves, bought feed, hay (in Ambo and Bako) and *enset* leaves (in Awassa) the most dominant of which is feeding conserved crop residues. However, the crop residues conserved in Ambo and Bako areas do not include maize stover since the whole of it is left to be consumed in the field right after grain harvest.

Table 6. Feed availability calendar in the study areas.

Study area	Months of relative feed abundance	Months of decreasing feed availability	Months of severe feed shortage	Months of increasing feed availability
Ambo	October, November, December	January, February, March	April, May, June	July, August, September,
Bako	September, October, November	December, January, February	March, April, May	June, July August
Awassa	August, September, October	November, December, January,	February, March, April,	May, June, July

Tables 7 and 8 present feed resources and their availability over time in Awassa, and Bako and Ambo areas, respectively, which are results from farmers' assessment/evaluations during focus group discussions. Availability of crop residues is better in districts with larger number of crops grown. Therefore, it is possible to state that feed shortage in Ambo is less severe than in Bako and in Bako it is less severe than in Awassa areas. Byproducts of *enset* (corm and leaves) and sugarcane (leaves and tops) are important feed resources in the Awassa area. Though communal grazing lands are not available in all the study areas, livestock obtain feed from natural pasture in wet seasons grazing on roadsides, around the homesteads and on land left by individual households for grazing.

Table 7. Feed resources available for livestock feeding in a year in Awassa area.

Feed resources	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Pasture					*	**	***	***	**	*		
Maize stover (green)						*	**	***	*			
Maize stover (dry)	*	*	*	*						***	***	**
Enset leaves	*	*					*	*	*			
Enset corm	**	**	**	*	*							
Sugarcane (tops/leaves)	*	*										

* increasing number of asterisks indicates an increase in relative abundance of the same feed resource over time.

Table 8. Feed resources available for livestock feeding in a year in Ambo (*) and Bako (+) areas.

Feed resources	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Pasture						 +	* ++	** ++	** ++	* +	*	
Maize stover (green)							 +	* ++	** ++	** +	*	
Maize stover (dry)	** +	*									 +	* ++
Other crop stubble	* +	* +	*									 +
Teff straw	* +	** ++	** ++	* +	* +	* +						

*, + = the number of asterisks/pluses indicates the relative abundance of the same feed resource over time.

Green maize stover availability follows the rainfall patterns. It starts to be available in June in Awassa and in July and August in Bako and Ambo, respectively. The use of green stover at the dough (*eshet*) stage is more extensively practiced in Awassa than in Ambo and Bako. This is because in Awassa most farmers sell a significant proportion of their maize grain in its green stage (*eshet*). During that period, green maize stover mainly from farmers without livestock is transported and sold in and around Awassa town (Figure 6). In feeding green stover during earlier stages than the *eshet*, priority is given to producing (milk, power) and young animals. However, when it is abundant, farmers offer their livestock indiscriminately mixed. Sometimes, special attention is given to fattening animals as depicted in Figure 7 where a farmer in the Awassa area feeds green maize stover for fattening sheep.

Figure 6. Green maize stover being transported to Awassa town for sale.

Figure 7. Fattening sheep eating green maize stover in Awassa.

4.1.2. Effect of variety on the yield and quality of maize stover

Table 9 shows the chemical composition of stovers obtained from the maize varieties harvested at the green (*eshet)* stage. Significant ($p<0.05$) differences were observed only in NDF and lignin fractions between varieties.

Table 9. Chemical composition of stover obtained from 15 maize varieties harvested at green (*eshet*) stage (g/kg DM) (n = 2).

Variety	Ash	CP	NDF	ADF	Lignin	Cellulose	Hemi-cellulose
BH543	55	74	$693a^{bcd}$	369	39^{bc}	330	324
BH542	50	70	698^{abc}	372	42^{b}	330	327
BH545	52	76	687^{bcd}	345	41^{b}	303	342
BH540	46	59	746^{a}	294	50^{a}	243	402
BH670	60	76	671^{bcdef}	317	42^{b}	275	355
BH660	46	73	678^{bcde}	368	41^{b}	327	311
Sidancho	77	84	622^{fg}	354	38^{bc}	315	318
Kuleni	41	69	680^{bcde}	355	38^{bc}	316	325
Gibe1	44	70	697^{abc}	307	40^{b}	267	394
Gutto LMS5	41	62	710^{ab}	382	42^{b}	340	328
BH140	55	77	666^{cdef}	353	35^{bcd}	318	313
Burre	31	59	692^{abcd}	353	38^{bc}	315	339
Arganne	62	64	637^{defg}	355	30^{de}	324	282
Wenchi	73	70	626^{fg}	344	32^{cd}	311	283
Jibat	75	74	609^{g}	329	27^{e}	301	280
Overall mean	**54**	**70**	**674**	**346**	**39**	**308**	**328**
SE	**9.12**	**4.92**	**16.52**	**31.14**	**2.32**	**31.33**	**31.43**

Means followed by different superscripts in a column are significantly different ($p<0.05$).
n = number of observations per variety.

The BH540 variety was the most fibrous and most lignified with NDF and lignin contents of 746 g/kg and 50 g/kg of stover dry matter, respectively. The CP content of the same variety was the least (59 g/kg) at the green stage. The variety called Jibat showed the least NDF and lignin contents with reasonably good CP (74 g/kg). This implies that green stover from Jibat is of the best quality.

As shown in Table 10 significant varietal differences ($p<0.05$) were observed in the ash, ADF, lignin and cellulose contents of the stovers at the mature (dry) stage whereas the differences in CP, NDF and hemicellulose fractions were not significant ($p>0.05$).

Table 10. Chemical composition of stover obtained from 15 maize varieties harvested at mature (dry) stage (g/kg DM) (n = 2).

Variety	Ash	CP	NDF	ADF	Lignin	Cellulose	Hemi-cellulose
BH543	62^{abc}	52	807	483^{abc}	55^{b}	428^{ab}	324
BH542	47^{c}	50	820	459^{cd}	60^{ab}	429^{ab}	361
BH545	49^{c}	45	817	478^{abc}	60^{ab}	418^{ab}	339
BH540	47^{c}	41	816	456^{cd}	62^{ab}	395^{abc}	360
BH670	58^{bc}	51	787	473^{bcd}	59^{ab}	414^{ab}	314
BH660	56^{bc}	47	788	488^{abc}	61^{ab}	427^{ab}	300
Kuleni	43^{c}	52	822	473^{bcd}	55^{b}	420^{ab}	348
Gibe1	45^{c}	51	831	440^{cd}	57^{b}	384^{bc}	391
Gutto LMS5	42^{c}	42	749	488^{abc}	62^{ab}	426^{ab}	263
BH140	52^{bc}	51	826	475^{abcd}	55^{b}	421^{ab}	351
Burre	57^{bc}	44	814	528^{a}	65^{a}	463^{a}	386
Arganne	62^{abc}	55	783	459^{cd}	46^{c}	413^{ab}	325
Wenchi	51^{bc}	38	776	476^{abcd}	46^{c}	430^{ab}	300
Jibat	72^{ab}	57	692	382^{e}	30^{d}	352^{c}	310
Pioneer	82^{a}	44	793	523^{ab}	62^{ab}	462^{a}	270
Overall mean	**55**	**48**	**795**	**472**	**56**	**419**	**322**
SE	**6.44**	**5.07**	**30.84**	**15.61**	**2.25**	**17.22**	**26.07**

Means followed by different superscripts in a column are significantly different ($p<0.05$)
n = number of observations per variety.

An important indicator of stover quality could be the protein content since it is the most limiting nutrient for efficient utilization of feed resources like maize stover for dry season feeding. The reported CP values were below 55 g/kg stover DM which indicates the magnitude of protein deficiency of maize stover to meet livestock requirements. However, the stover CP values varied considerably from 38 - 57 g/kg DM (50%) in variety Wenchi and Jibat, respectively. The existence of this variation and the insignificant, though negative, correlation (r = -0.295) between grain yield and CP contents of the stovrers indicate that there is a potential to breed maize for better stover CP contents embedded in the general focus of improving stover yield and quality.

As shown in Table 11, varietal differences in *in vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) values between maize stover were significant ($p<0.05$). The variety with the name Jibat showed significantly higher IVOMD and ME values than the other varieties while the respective values for *Burre* were the least. This disagrees with farmers' ratings of palatability when viewed from its digestibility and energy contents. If stover digestibility is considered as an indicator of potential palatability, there is a disagreement between farmers' ratings of maize varieties in Ambo and Bako areas and the *in vitro* observation on their digestibility. The order of varieties according to farmers' ratings of palatability is *Burre*>BH540>BH660 whereas in terms of observed digestibility the order is BH660>BH540>*Burre*. This disagreement could be attributed to the differences in the proportion (in the stover) and hardness of their stems. However, farmers' ratings of maize varieties for palatability in Awassa agrees with the observed stover digestibility where Pioneer>BH540.

Table 11. *In vitro* organic matter digestibility (IVOMD), digestible DM yield (DSY) and energy (ME) values of the stovers of the 15 maize varieties harvested at mature (dry) stage. (n=2).

Variety	IVOMD (g/kg DM)	DSY (t DM/ha)*	ME (MJ/kgDM)
BH543	60.21^{bc}	4.81^{cd}	8.95^{bc}
BH542	56.31^{cde}	4.89^{cd}	8.35^{cde}
BH545	56.78^{cde}	4.24^{d}	8.48^{cde}
BH540	54.04^{de}	3.87^{d}	8.08^{de}
BH670	58.45^{bcd}	6.83^{bc}	8.71^{bcd}
BH660	57.02^{cde}	5.85^{cd}	8.51^{cd}
Kuleni	59.77^{bc}	5.28^{cd}	8.91^{bc}
Gibe1	59.77^{bc}	5.67^{cd}	8.92^{bc}
Gutto LMS5	55.60^{cde}	4.17^{d}	8.29^{cde}
BH140	59.53^{bc}	4.51^{cd}	8.86^{bc}
Burre	53.25^{e}	5.71^{cd}	7.91^{e}
Arganne	61.29^{b}	5.91^{cd}	9.21^{b}
Wenchi	62.25^{b}	9.08^{a}	9.29^{b}
Jibat	67.24^{a}	8.50^{ab}	10.02^{a}
Pioneer	58.49^{bcd}	5.05^{cd}	8.67^{bcd}
Overall mean	58.70	5.62	8.74
SE	1.38	0.71	0.19

Means followed by different superscripts in a column are significantly different ($p<0.05$).
*DSY was a calculated value based on stover yield and IVOMD.

n = number of observations per variety.

There were no significant variations ($p>0.05$) between varieties in their grain and total biomass yield (Table 12). BH660 was found to be the highest grain yielder and Kuleni the least. The absence of significant varietal difference ingrain yield observed in the current study disagrees with that of Adugna *et al.* (1999). This may be attributed to differences in the set of varieties used. However, varieties exhibited significant variations in stover yield. Significantly higher stover yield was recorded for Wenchi than the rest of the varieties.

Table 12. Grain, stover, cob and total biomass yield of the 15 maize varieties (n=2).

Variety	Yield (t DM/ha)			
	Grain	Stover	Cob	Total biomass
BH543	8.17	7.99[bc]	1.30	17.46
BH542	7.21	8.71[bc]	1.83	17.75
BH545	8.90	7.43[c]	1.85	18.17
BH540	7.58	7.16[c]	1.47	16.21
BH670	8.93	11.69[b]	1.90	22.52
BH660	9.20	10.01[bc]	1.34	20.55
Kuleni	4.80	8.83[bc]	0.99	14.62
Gibe1	6,72	9.02[bc]	1.17	16.91
Gutto LMS5	6.26	7.60[bc]	1.21	15.07
BH140	5.71	7.62[bc]	1.13	14.45
Burre	6.35	10.78[bc]	1.27	18.40
Arganne	5.88	9.57[bc]	1.18	16.62
Wenchi	5.53	14.59[a]	1.09	21.20
Jibat	5.18	8.64[bc]	0.97	18.76
Pioneer	8.63	9.48[bc]	1.72	18.99
Overall mean	**7.00**	**9.48**	**1.36**	**17.84**
SE	**1.50**	**1.20**	**0.27**	**2.57**

Means followed by different superscripts in a column are significantly different (p<0.05).
n = number of observations per variety.

All feed related parameters had highly significant (p<0.01) correlations with stage of harvest except the ash contents (Table 13). Stage of harvest had negative and significant correlations with CP, ME, stover yield (SY) and IVOMD whereas its correlations with NDF, ADF and ADL were positive and significant. These findings agree with that of Adugna *et al*. (1998) where decreases in stover yield and its nutritive value with increasing stage of maize grain maturity at harvest were reported. These are strong and valid confirmations that total feed and its quality from maize seriously decline from the green/*eshet* or dough stage to full maturity. This implies that conservation of the stover harvested at the *eshet* stage helps ensure availability of maize stover with better quality for dry season feeding. It could be exercised in areas like Awassa where a considerably large volume of green stover is harvested due to the practice of selling maize for *eshet*. Moreover, systematic defoliation and conservation could be practiced up to the level where the physiological processes for grain filling are not significantly affected. However, the extent to which this can be practiced requires investigations.

Table 13. Correlation coefficients (r) of the measured variables with stage of harvest on maize stover (n=56).

	Measured variables						
	Ash	CP	NDF	ADF	ADL	IVOMD	SY
r	0.049	-0.812**	0.804**	0.851**	0.734**	-0.602**	-0.671**

** Correlation is significant at the 0.01 significance level.
n = number of observations.

Table 14 shows the correlation of grain yield with stover yield and its quality. Grain yield showed positive but insignificant ($p<0.05$) correlations with stover yield and NDF contents. However, its correlation with stover ADL content was positive and significant. Grain yield was not significantly correlated to CP content of stover, but significantly and negatively correlated to IVOMD and ME values of the stover. Absence of significant differences in grain yield and the considerable and significant variations in the yield and quality of stover observed between the studied maize varieties support the view that improving the yield and quality of maize stover through breeding and selection without significantly affecting grain yield is possible.

Berhanu (2009) reported significant positive correlations between grain yield and stover yield whereas the correlation between grain yield and the nitrogen content of sovers of the maize hybrids was negative and significant. Contrary to this report, no significant correlations between grain yield and both yield and CP content of maize stovers were found in the current study.

Table 14. Correlation coefficients (r) of grain yield and stover yield and stover quality (n=30)

	Grain yield	CP	NDF	ADF	ADL	ME	IVOMD	Stover DM yield
Grain yield								
CP	-0.295							
NDF	0.126	-0.230						
ADF	0.252	-0.538**	0.468**					
ADL	0.461*	-0.468**	0.564**	0.690**				
ME	-0.415*	0.579**	-0.506**	-0.646**	-0.926**			
IVOMD	-0.410*	0.599**	-0.508**	-0.639**	-0.920**	0.999**		
Stover DM yield	0.019	-0.019	-0.201	-0.158	-0.448*	0.348	0.342	
Digestible stover DM yield	-0.092	0.130	-0.314	-0.321	-0.635**	0.563**	0.556**	0.967**

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level
n = number of observations.

However, absence of any significant correlations (p>0.05) between grain yield and both NDF and ADF contents of maize stovers agrees with that reported by Berhanu (2009). Stover ME and IVOMD exhibited positive and nearly 100% correlation indicating that a measure of digestibility of maize stover is a measure of its metabolizable energy.

Figure 8 presents the observed yields of grain, stover and digestible stover between variety categories. There were no significant (p>0.05) variations between variety categories (hybrid, OPV and landrace) in grain yield and both yield and quality of their stovers. However, hybrids exhibited the highest grain production and digestible stover yield.

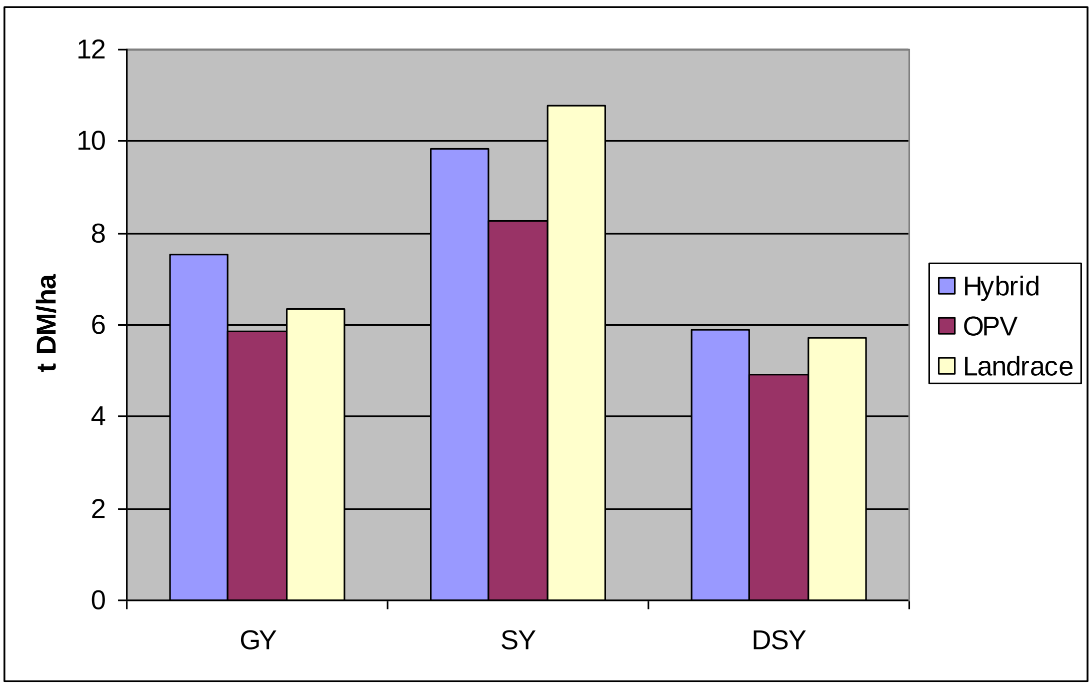

Figure 8. Observed yields of grain (GY), stover (SY) and digestible stover (DSY) in the studied maize varieties categorized into hybrid, OPV(open pollinated variety) and landrace

In conclusion, the observed variations between the varieties in the measured feed related parameters but with no significant variation in grain yield indicate the possibility of manipulating some traits in the effort to improving the yield and quality of maize stover through breeding and/or selection without significantly affecting grain yield. Therefore, there is a need to work with animal nutritionists in the process of maize technology generation when targeting the mixed crop-livestock system of agricultural production. On the other hand, as the yield and quality of maize stover deteriorates as the stage of grain maturity increases, employing applicable system of feeding livestock on stover before the last stage of maturity is advisable

4.2. Constraints to the Linkage between the Maize and the Livestock Subsystems

An integrated maize - livestock system is meant to refer to a system where both of the enterprises are owned by the same household and the flow of resources between the two enterprises offers opportunities towards improving agricultural productivity and sustainability. An integrated maize-livestock system makes effective use of marketable and non-marketable resources for a set agricultural goal – in Ethiopia's case, food security both at household and national levels. Livestock contribute to maize production through draught power, cash and manure. The cash coming from livestock helps cover expenditures for input purchase (mainly improved seed and fertilizer) and other household cash demands. In addition to supplying feed, cash obtained from the sale of maize grain could also contribute to livestock production, e.g., for restocking, for covering costs of veterinary services and other household demands helping retain livestock that could potentially be sold for the purposes. The conceptual outline for resource flows in an integrated maize-livestock system is presented in Figure 9.

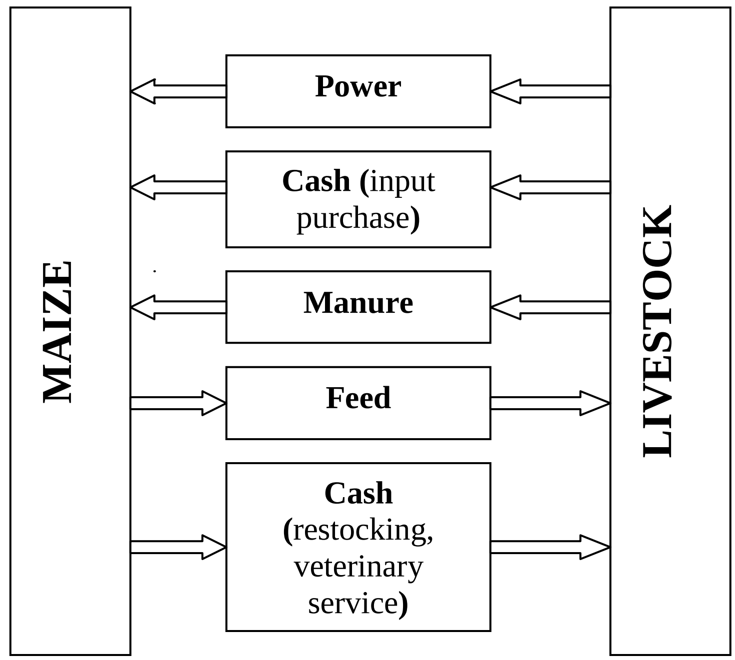

Figure 9. Schematic presentation of resource flows in an integrated maize-livestock production system.

Any issue that weakens and/or interrupts this interaction or flow of resources partly or fully is considered as a constraint to the linkage between the maize and the livestock subsystems. These constraints are discussed categorized into socio economic and biophysical constraints, and institutional constraints supported by descriptive data. Socio-economic and biophysical constraints include population pressure and big family size, and prevalence of diseases and pests. The institutional constraints on the other hand take into account issues related to the balance in the research focus, and problems associated with the extension and other services.

4.2.1. Socio-economic and biophysical constraints

4.2.1.1. Population pressure and large family size

Ethiopia has the second largest human population on the African continent (UNDP, 2009). Its population grows at a steady rate- 2.7% per annum (CSA, 2007). To feed this increasing human population, more and more land has been coming under cultivation. This is accompanied by extensive disturbance of the natural ecology through deforestation resulting in changes in the temperature and rainfall regimes of a given ecological system. Low amounts of rainfall and irregularity in its pattern cause crop failure due to moisture stress or confusions in planting calendar. A 10% drop in rainfall (below the long term national averages) resulted in an average drop of 4.2% in cereal yields in the country (Dagnachew, 2008). Land degradation is also one of the consequences of such a disturbance affecting maize production and productivity due todecreasing soil fertility.

As a result of population pressure, land holding per family becomes smaller and smaller. For example, Byerlee *et al*. (2007) showed the magnitude of decrease in per capita land holding from 0.5 ha in the 1960s to only 0.2 ha by 2005 in Ethiopia. This impacts feed availability as farmers tend to cultivate more land available to them to produce enough food for their family at the expense of their grazing lands. With their perception of the urgency of securing grain dictated by large family sizes, farmers do not put feed related parameters as selection criteria for maize varieties.

In the current study, households were found to have large family size and the mean family sizes per household were 6.5, 7.2 and 7.5 persons for Ambo, Bako and Awassa districts, respectively with the maximum ranging from 15 in Ambo to 24 persons in Bako the figure in Awassa being 17 (Table 15). These figures indicate the magnitude of the burden for a household to produce enough grain to feed the large family. However, the mean household land holdings cultivated are virtually small ranging from one hectare in Awassa to three hectares in Ambo (Table 16). This was evidenced by the fact that 54, 61 and 79% of the sample farmers in Ambo, Bako and Awassa areas, respectively reported that the land they own is not sufficient to produce enough grain to feed their families (Table 17). In order to fulfill their demands for additional land, sharecropping and renting are the strategies employed. However, they do not get enough land to rent or sharecrop. The shortage of land usually motivates them to cultivate more land accessible to them and the piece that is left for grazing is the immediate target which in turn aggravates feed shortage. Extended dry seasons and severe overgrazing make the carrying capacity of the piece of land that is left for grazing very low and unproductive by destroying the plant composition and depleting the regrowth potential of important species.

Table 15. Average family size per household in the study districts.

District	n	Minimum	Maximum	Mean	SD
Ambo	140	1	15	6.46	2.512
Bako Tibe	120	2	24	7.17	3.211
Awassa	90	1	17	7.54	3.058

SD = standard deviation; n = number of respondents.

Table 16. Mean land size owned (ha) per household by use pattern in the study districts.

District	Cultivated	Grazing	Fallowed + Homestead	Total
Ambo (n=140)	3.07	1.43	0.91	5.41
Bako Tibe (n=140)	2.54	0.64	0.66	3.84
Awassa (n=140)	1.04	0.35	0.33	1.72

n = number of respondents.

Table 17. Percentage of farmers who reported the land they own is not enough to produce food to feed their families by district.

District	Farmers who complained about land shortage	
	n	%
Ambo (n=140)	76	54
Bako Tibe (n=120)	73	61
Awassa (n=90)	71	79

n = number of respondents.

4.2.1.2. Prevalence of diseases and pests

Ethiopian agriculture is highly affected by the prevalence of diseases and pests of crops and livestock. Livestock diseases are among the constraints that affect the integration of maize and livestock subsystems in the major maize growing areas of the mixed crop-livestock system by causing high mortality rates of animals. For example, EARO (2001b) estimates an annual loss of 2.4 – 3 million heads of cattle due to mortality. On the maize side, released varieties once believed to be resistant to certain diseases and pests go out of production due to disease and/or pest problems. This happens either because of the occurrence of new diseases or increased virulence of existing diseases as a result of ecological changes. The incidence of diseases and pests causes total crop failure or significant yield reductions both in maize grain, and stover which could be used to feed livestock otherwise.

Diseases and parasites which affect livestock were reported by farmers in the study districts during focus group discussions supported by information from district offices of agriculture and rural development are indicated in Table 18. The situation is aggravated by the fact that livestock are pushed to abandoned and marshy areas where disease and parasite infestations are very high. Some of the diseases reported like anthrax, black leg and mastitis are known to be diseases of intensification. Any effort towards an intensified maize-livestock system should take preventive, treatment and control strategies and their effective implementation as a crucial step. However, the situation in the study districts is constrained by several problems.
Though the proportions of farmers who get veterinary services were not as low as what would be expected (Table 19), the quality of the services is highly affected by the technical inefficiency of veterinary personnel and lack of appropriate physical facilities for diagnosis and treatment of livestock diseases. For example, only one junior veterinary technician is assigned to supervise/attend veterinary issues in three to five peasant associations in the study areas. Besides the number, their technical capacity limits them as they are with a diploma level training. Vaccinations are practiced when national and/or regional campaigns are initiated. That is why repeated appeals by livestock owning farmers for the treatment of

disease outbreaks did not get fast responses and appropriate measures. This was especially reported by farmers in the Bako area during the focus group discussions

Table 18. Common livestock disease and parasite problems reported by district.

Disease/parasite reported	District		
	Ambo	Bako Tibe	Awassa
Black leg	*	*	**
Anthrax	**	*	*
Pasteurolosis	*	*	NR
Trypanosomiasis	**	***	*
Internal and external parasites	*	*	*
Mastitis	*	*	*

NR = Not reported.
* indicates the relative importance of the disease over sites.
.

Table 19. Percentage of farmers with access to veterinary services.

District	Veterinary services
Ambo	58
Bako Tibe	93
Awassa	80

Table 20 presents rank of key constraints to livestock production identified by farmers in the study districts. Feed shortage alone, as responded in the farmers' way of perception, ranked first in Awassa, second in Ambo and third in Bako Tibe. However, shortage of land for grazing is again to mean feed shortage. Therefore, overall feed shortage is the most critical livestock production problem in all of the study districts followed by diseases. Disease problem was reported with a much higher frequency in Bako Tibe than in Ambo and Awassa. This is because the Bako Tibe district is located in and around the Gibe Valley which is known for its high infestation rate with tsetse fly which transmits trypanosomiasis.

Table 20. Rank of major constraints associated with livestock production at each site as identified by farmers.

Constraint	Rank of constraints by district		
	Ambo	Bako Tibe	Awassa
Disease	3 (73)*	1 (92)	4 (42)
Feed shortage	2 (76)	3 (63)	1 (74)
Shortage of land for grazing	1 (89)	2 (81)	2 (60)
Lack of capital for initial investment	4 (35)	4 (23)	3 (55)

* Numbers in parenthesis refer to the number of farmers who reported the problem.

Diseases prevalence coupled with feed shortage reportedly influenced the number and productivity of livestock owned by households. The number of farmers who own at least one ox was 105 (75 %), 87 (72 %) and 40 (44 %) in Ambo, Bako Tibe and Awassa districts, respectively (Table 21). This shows that a considerable proportion of the farmers are without an ox for cultivation. Though there are established social norms and arrangements of sharing animals for power, those without oxen are liable to maize failure due to delayed planting as the priority in the arrangements goes for those who own the oxen. Almost all sample farmers in the study districts use animal power for transporting maize grain to market (Table 22). This is strong evidence which shows the extent of farmers' dependence on animal power/livestock for household activities in addition to using them for cultivating their lands. Animals that are used for transporting maize grain to market are equines mainly donkeys. As shown in Table 21, farmers located far from market places tend to keep equines. It seems that the reason why 92 (66 %) of the sample farmers in Ambo keep at least a donkey as compared to 26 (22 %) in Bako Tibe and 21 (23 %) in Awassa districts is distance to market centers. Obviously, manure is among the important resources from livestock that could be used for fertilizing maize plots. However, it was found that its use is very little in all of the study areas due to small livestock holdings. Even the amount obtained from households with larger livestock holdings is confined to the use for backyard maize production.

Table 21. Composition and herd structure of livestock owned per household in the study districts.

District	Statistics	Livestock type/species							
		Ox	Cow	Calf	Heifer	Bull	Sheep	Goat	Donkey
Ambo	n	105	118	105	80	79	50	47	92
	Min.	1	1	1	1	1	1	1	1
	Max.	6	35	10	8	6	15	15	5
	Mean	2.42	2.89	2.06	1.9	1.87	3.38	4.34	1.51
Bako Tibe	n	87	87	76	59	57	18	7	26
	Min.	1	1	1	1	1	1	1	1
	Max.	14	15	8	15	10	20	4	3
	Mean	2.37	2.89	2.18	2.31	1.88	3.89	1.71	1.58
Awassa	n	40	72	45	9	14	20	19	21
	Min.	1	1	1	1	1	1	1	1
	Max.	4	12	4	10	5	6	5	4
	Mean	1.45	1.76	1.51	2.00	1.36	2.10	1.37	1.33

n = number of households who reported as having the livestock type/species.

Table 22. Mean distance to market (km), and percentage of farmers who sell maize grain and their means of transport.

District	Distance to market	Sell maize (% of total respondents)	Means of transport (as % of respondents who sell maize)						
			Pack animal	Human power	Pack animal + human power	Animal drawn cart	Vehicle	Pack animal + animal drawn carts	Animal drawn carts + vehicle
Ambo	8.2	22	79	6	15	0	0	0	0
Bako Tibe	4.8	70	44	1	6	38	2	8	1
Awassa	2.9	70	33	0	0	42	4	21	0

4.2.2. Institutional constraints

4.2.2.1. Balance of the research focus and professional thinking

Agricultural research in Ethiopia is mainly focused on crops and related issues. This is reflected by the imbalance in staffing and financial resource allocation. The budget share allotted to crops and livestock research processes/Directorates for five years is shown in Table 23. In all of the years until 2009, the budget share for livestock research did not surpass half of the amount allotted for crops research. That difference in terms of percentage of the total budget is a very simple evidence that could show the imbalance. But the actual causes and picture go beyond that extent. Except in few, in most of the agricultural research centers, the primary mandate for their establishment goes for crop issues. This is linked to the motto of "food security" which has been echoed for several decades. Policy implementers have been considering livestock as a secondary enterprise (Habtemariam, 2003). Regardless of the importance of livestock in rural livelihoods, where farmers in the study areas state that "if there are no livestock, there is no life", the focus of research seems to be more on crops. As one of the commodity crops for food security, maize has got by large better attention than livestock.

The maize research has been predominantly focusing on the development and release of maize genotypes that are adaptable and high yielding. The parameters considered through the process are all related to grain yield. Feed related traits were considered bad and negatively correlated with grain yield until very recently that maize breeders are convinced by evidences that inform the possibility of combining food and feed traits (Adugna, 2002; Devendra and Pezo, 2004; Singh *et al*., 2004). Nevertheless, the state of consensus among professionals on the way forward has not been solidified yet. The absence of any involvement of livestock scientists in the maize breeding and selection programs in the EIAR system could be an evidence to support the stated status.

Table 23. Annual capital budget share (in thousand Birr) allotted to crops and livestock research processes/Directorates for five years (2005-2009) in the Ethiopian Institute of Agricultural Research.

	2005		2006		2007		2008		2009	
Program/Directorate	Amount	% of total	Amount	% of total	Amount	% of total	Amount	% of total	Amount	% of total
Crops Research Process/Directorate	9495	5.32	10097	6.11	9970	8.94	9884	16.06	12483	13.83
Livestock Research Process/Directorate	4493	2.52	4459	2.70	4226	3.79	4804	7.80	8600	9.53

Source: Planning Office, Ethiopian Institute of Agricultural Research (personal communication)

Despite the global trend and professional thinking towards agricultural intensification through crop and livestock integration, the situation in Ethiopia in terms of research effort is below what could be expected. People view agricultural problems through their narrow professional windows being highly confined to discipline/enterprise specific activities. Regardless of the importance of livestock in the agricultural sector, even to the production of cereals like maize through the resources farmers get from, the research efforts to integrate maize and livestock is not up to the level the scenario demands. Feed shortage has been rated as the most important livestock production problem in Ethiopia. However, the conventional thinking to solve the problem has focused mainly on the improvement of grazing land productivity (which is almost nonexistent on lands that are in the hands of smallholder farmers in the mixed crop - livestock system) and increase fodder availability through the dissemination of forage technologies to farming communities which is again constrained by shortage of land and seeds. Realizing the potential of crop residues for livestock feeding, research efforts on how to improve their utilizations were one of the areas of intervention that have been tried for many years (EARO, 2001b). Attempts to improve maize stover utilization were employing different supplement strategies and treatment options. These strategies and options are labor and, more importantly, capital intensive which make them unaffordable to smallholders. Moreover, unavailability of feed resources for supplementation complicates the problem. Therefore, development of maize genotypes that could provide better quality and quantity feed should have presumably been the best option and focus of research towards an integrated and sustainable smallholder maize and livestock production in Ethiopia.

4.2.2.2. The extension system and associated functions

In spite of the commendable magnitude of focus and efforts put forward to bringing success in agricultural development by the government through strengthening the agricultural extension, there are still difficulties facing the system particularly when viewed from the angle of integrating the maize and the livestock subsystems.

4.2.2.2.1. Issues related to technology popularization

For a successful adoption of a technology, popularization is a crucial step as it promotes better social inclusion in the use of the technology. This could be achieved through demonstrations and training. Organizing farmers' field days is one of the mechanisms to demonstrate a technology to end users. These are particularly important in the Ethiopian condition where the education level of farmers is considerably low. For example, 44 %, 38 % and 42 % of the sample farmers in Ambo, Bako Tibe and Awassa, respectively were without formal education (Table 24).

Table 24. Proportion (%) of the household heads by education level (years of schooling).

District	Education level				
	0	1-6	7-12	Mean	SD
Ambo(n=140)	44	30	26	3.64	3.904
Bako Tibe(n=120)	38	41	22	3.45	3.295
Awassa (n=90)	42	45	14	2.94	3.043

SD = standard deviation; n = number of respondents.

Teaching farmers on improved agricultural practices through frequent visits to farmers' fields, particularly in the growing season is an important extension activity to enhance the uptake of a technology at a larger and wider scale. However, as shown in Table 25, the percentage of farmers who got extension visits at least once during the growing season is markedly low in Ambo (17) and Bako Tibe (27) though the figure in Awassa (56) looks encouraging.

Table 25. Number and proportion (%) of farmers who got their maize farm visited by extension agents at least once during the growing season.

District	Extension agent visit	
	n	%
Ambo (n=135)	23	17
Bako Tibe (n=118)	32	27
Awassa (n=88)	49	56

n = number of respondents.

Moreover, the proportion of farmers who got training on improved agricultural practices is less than one third (Table 26) whereas participations in farmers' field days (Table 27) were limited to less than a quarter of the sample farmers in all of the study districts. Looking at those levels of participation in training and field days, it is evident that the focus is more on crops/maize than livestock. A similarly low level of participation in livestock packages and training as compared to that of crops' has been reported by EEA/EEPRI (2006). Even the much higher figures of participation on both enterprises reported in the current study do not necessarily reflect the magnitude of efforts made to integrate maize and livestock subsystems. Had it been like that, the practice of farmers in Ambo and Bako areas where maize stover is left to be consumed by animals and finished/spoiled in the field would have been changed. Absence of extension education on how to integrate maize and livestock was reflected by the unchanged practice of not using collected and conserved maize stover in Ambo and Bako Tibe in spite of the reported severity of feed shortage particularly in the dry season.

Table 26. Proportion of farmers who participated in training and the distribution by type of training.

District	Participation		Participation by type of training (as % of farmers participated)		
	n	%	Crops	Livestock	Both
Ambo (n=140)	24	17	12	4	84
Bako Tibe (n=120)	26	22	36	8	56
Awassa (n=90)	28	31	25	11	64

n = number of respondents.

Table 27. Participation in farmers' field days.

District	Participation		% participation by enterprise		
	n	%	Maize	Livestock	Both
Ambo (n=140)	31	22	26	0	74
Bako Tibe (n=120)	26	22	19	0	81
Awassa (n=90)	22	24	50	0	50

n = number of respondents.

4.2.2.2.2. The maize input system

Though the proportion of farmers who grow improved maize varieties is reasonably high in Bako Tibe and Awassa districts (Table 28), the seeds they use may not necessarily be of the required quality. They simply describe ‘improved’ if the seed they use is not their local variety. A significant proportion of farmers use second generation seeds since they can’t get seeds of their preference (Table 29). As learned from farmers’ experience, the use of second generation hybrid maize seeds causes yield reductions of up to 50%. The maize seed system suffers from a serious shortfall from the demand. Dawit *et al*. (2007) reported only a 53% success rate in 2004/05 cropping season in terms of satisfying the demand for improved maize seeds.

Table 28. Percentage of farmers who grow maize by variety type.

District	Variety type		
	Local	Improved	Both
Ambo (n = 135)	69	14	17
Bako Tibe (n = 118)	9	68	23
Awassa (n = 88)	29	67	4

n = number of respondents.

Table 29. Percentage of farmers who do not get preferred maize seeds and thus use second generation hybrid seeds.

District	Shortage of preferred variety (% of total)	Use second generation seeds as an option
Ambo (n = 135)	32	26
Bako Tibe (n = 118)	27	25
Awassa (n = 88)	38	54

n = number of respondents.

In addition to the overwhelmingly reported shortage of inputs in terms of quantity documented during focus group discussions, farmers ranked high price of inputs and their late supply as the most critical maize production problem in all of the study sites (Table 30). These are indications that the input system is inefficient and ineffective.

Table 30. Rank of key constraints in maize production identified.

	District		
Constraint	Ambo (n=135)	Bako Tibe (n=118)	Awassa (n=88)
High price of inputs	1 (135)*	1 (118)	1 (88)
Late supply of inputs(seed and fertilizer)	2 (122)	2 (112)	2 (73)
Land shortage	4 (26)	3 (34)	3 (61)
Late onset of rain	3 (49)	4 (21)	4 (23)

* Numbers in parenthesis refer to the number of farmers who reported the problem.
n = number of respondents.

4.2.2.2.3. The credit system

The proportion of farmers who had access to credit service in Ambo and Bako Tibe districts looks reasonably good and very much higher than that of Awassa where 98% of the sample farmers had no access to credit service (Table 31). However, those who had an access to credit service reported problems about the credit service that they get. The widely stated problems include high interest rate, request to pay debt early in the dry season and down payment in order of importance. Request for debt repayment before the selling price of maize grain rises coupled with the stated high price of inputs creates a serious and devastating problem to farmers which forces them to sell livestock (including oxen) and other belongings. For example, among those who experienced failure to pay their debts from the sale of grain, 79% in Ambo and 71% in Bako Tibe sold livestock (Table 32). Contracting out land was also reported as one of the practices. These all negatively affect the farmers' success rates in their engagements using both maize and livestock.

Table 31. Proportion (%) of farmers who get credit service.

District	Credit service			
	Yes		No	
	n	%	n	%
Ambo (n=140)	117	84	22	16
Bako Tibe (n=120)	89	74	31	26
Awassa (n=90)	2	2.	89	98

n = number of respondents.

Table 32. Proportion (%) of farmers who experienced failure to pay debts from the sale of grain and consequently sold livestock.

District	Failed to pay debts	Sold livestock
Ambo (n=140)	60	79
Bako Tibe (n=120)	69	71
Awassa (n=90)	0	0

n = number of respondents.

In conclusion, the stated problems are constraining the linkage between the maize and livestock subsystems by limiting the resource flows between, and the potential socioeconomic benefits from maize and livestock integration. Continuous extension education on natural resource conservation along with lessons on family planning is desirable to limit the effect of population pressure on the ecology and natural resource base. Moreover, research and extension support focusing on the generation and adoption of agricultural technologies that would help maximize output per unit of land from maize and livestock operations together is required**.**

4.3. Factors that affect farmers' preference for improved maize variety

The list of preferred maize varieties included BH660, BH540 and Pioneer. Characteristics of the varieties in terms of grain yield, stover yield, digestibility of stover and digestible stover yield are presented in Table 33. On the other hand, descriptive summary for the demographic, socio economic and institutional characteristics of the sample farmers considered in the analysis are shown in Table 34.

Table 33. Grain yield, stover yield, stover digestibility and digestible stover yield of the preferred maize varieties.

Variety	Grain yield (t DM/ha)	Stover yield (t DM/ha)	Digestibility (g/kg DM)	Digestible stover yield (t DM/ha)
BH660	9.20	10.01	570	5.85
BH540	7.58	7.16	540	3.87
Pioneer	8.63	9.48	585	5.05

Table 34. Demographic, socio-economic and institutional characteristics of farmers (n=181)

Variable	Minimum	Maximum	Mean	SD
Age of the household (HH) head (years)	20	81	41.18	12.84
Education level of the HH head (years of schooling)	0	12	3.29	3.23
Farming experience (years)	1	55	21.21	11.63
Family size (number)	2	24	7.38	3.12
Farm size (ha)	0	10	1.94	1.77
Livestock ownership (TLU)	0	53.08	4.46	5.73
Distance to market center (minutes)	0	180	37.74	32.25
Distance to development office (minutes)	0	180	34.20	30.35
Potential Utility Index (PUI)	70.5	73.2	72.16	1.27
Access to credit (1=Yes; 0=No)	0	1	(0.53)*	

*mean proportion; HH = household; TLU = tropical livestock unit; SD=Standard Deviation

Table 35 presents parameter estimates of the multinomial logit model. Differences in location and education level had no significant (p>0.1) effect on the preference of BH660. However, the effects of these variables were negative and highly significant (p<0.01) on the choice of Pioneer. These imply that Pioneer is more likely to be adopted in Awassa than in Bako, and those farmers (in both locations) with higher education level are less likely to grow Pioneer. Farm size did not have a significant effect on the preference of BH660; however, farmers with larger farm size are less likely to choose Pioneer.

Table 35. Parameter estimates of the multinomial logistic regression.

Variable	BH660		Pioneer	
	Coefficient	Standard Error	Coefficient	Standard Error
LOC	2.918	2.643	-160.743***	8.173
EDU	-0.052	0.115	-0.404***	0.070
FRMEXP	0.258**	0.127	0.176**	0.088
FAMSZ	-0.882*	0.456	-1.495***	0.339
FARMSZ	-0.628	0.716	-27.738***	0.711
LVSTK	0.533*	0.307	0.383	0.346
CRDIT	1.122	1.238	6.821***	1.309
DISEXT	-0.026	0.052	-0.151**	0.059
PUI	32.299***	0.093	66.525***	0.058
Constant	-2320.401		-4686.366	
No. of Observations		181		
Log Likelihood		-2.998e-15		
Pseudo R^2		1.000		

Note: BH540 is a reference category. ***, ** and * are meant to indicate the significance of the corresponding coefficient estimates at 1%, 5%, and 10%, respectively.

The other variable which had a significantly ($p<0.01$) positive effect on the preference of both BH660 and Pioneer was potential utility index. This implies farmers prefer BH660 and Pioneer for their better yield of grain and digestible stover. Farmers with better farming experience are able to weigh the overall utility of the varieties of maize they grow. However, education had no significant effect on the preference of BH660, while this variable exhibited highly significant ($p<0.01$) negative influence on the preference of Pioneer, and this could be explained by the reason that most educated farmers are considered as model farmers and go for and/or prefer varieties that are supplied through the government facilitated (extension) channel.

Family size had significant negative influence on the preference of both BH660 and Pioneer. This came against the hypothesis that households with larger family size are more likely to grow maize varieties with better grain yield since the two give higher grain yields than BH540. Moreover, the positive and significant ($p<0.1$) effect of livestock ownership on the preference of BH660 over BH540 suggests that farmers with livestock are more likely to grow maize varieties with better total and digestible stover yields.

Access to credit and walking distance to the nearest extension office had no effect on the preference of BH660. However, walking distance to the nearest extension office negatively and significantly affected the adoption of Pioneer. Farmers who have access to credit are more likely to prefer Pioneer, and this may be due to the fact that Pioneer seeds are more expensive than other improved seeds. The model results also showed that potential utility index had highly significant positive influence on the adoption of BH660 and Pioneer implying that the potential utility index, of a variety which includes the feed related parameters, is an essential variable that needs to be included in the process of maize variety generation and release.

The results generally support the hypotheses set regarding factors that influence farmers' preference to improved maize varieties, and are with possible implications that livestock owning farmers do show preference to maize varieties that are with desirable stover characteristics for feeding livestock in addition to grain yield.

4.4. Characteristics of Maize-Livestock Innovation Systems

This section of the dissertation has two major parts: the national perspective, and the cases of Awassa, Bako and Ambo areas**.**

4.4.1. The national perspective

4.4.1.1. Actors, their roles and competencies

A wide array of actors relevant to the maize – livestock innovation system were identified which included public and private sector actors, NGOs, international research institutes and community based organizations (CBOs). Following Hall *et al.* (2006), the actors are categorized into five domains; the demand, enterprise, intermediary, research, and policy and support structure (Figure 10). Their roles and competencies are described and discussed in the following subsequent sections.

4.4.1.1.1. The research domain

The Ethiopian Institute of Agricultural Research (EIAR), which operates under the Ministry of Agriculture and Rural Development (MoARD), is the key institute responsible for the coordination of agricultural research in Ethiopia. It has been engaged, through its Crops Research Directorate, in maize research for decades with its core functions including maize breeding, production of breeder or foundation seed, and supplying breeder/foundation seed to basic seed producers. EIAR's activities are carried out at Melkassa, Bako, Ambo and Awassa Agricultural Research Centers and other Regional Agricultural Research Institutes (RARIs). Maize research activities run by Higher Learning Institutes (HLIs) add to the efforts by the institute. The HLIs that have been making important contributions include Haramaya University (formerly Alemaya University), the Jimma College of Agriculture of Jimma University, Ambo University, Mekelle University's Institute of Dryland Agriculture, and Hawassa College of Agriculture at Hawassa University.

The Livestock Research Directorate of EIAR is also responsible for coordinating livestock research in the country where its functions include generation of livestock technologies that could be multiplied by others. The livestock research has focused on Milk and Traction, Meat and Poultry, Fishery, Forage, and Animal Health as thematic areas. It cooperates with RARIs and HLIs. The HLIs mentioned above are also partners in the area of livestock research, and the Addis Ababa University's Faculty of Veterinary Medicine is an addition. Livestock research in the EIAR system started decades ago. However, in relation to the endowment of the country with huge livestock population and many different species, and varied agro-ecologies suitable for livestock production, the impact of research on production and productivity is far below what might be expected. The multiplication and uptake of livestock technologies is constrained by lack of appropriate support services (in particular credit) and access to other inputs (artificial insemination, vaccination). Though animal health research has been one of the focal themes, the country still loses a significant percent of its livestock due to disease. For example, EARO (2001b) estimated annual mortality rates in cattle, sheep and goats to be about 10, 15 and 12 %, respectively. The key actors in the research domain and their roles are summarized in Table 36.

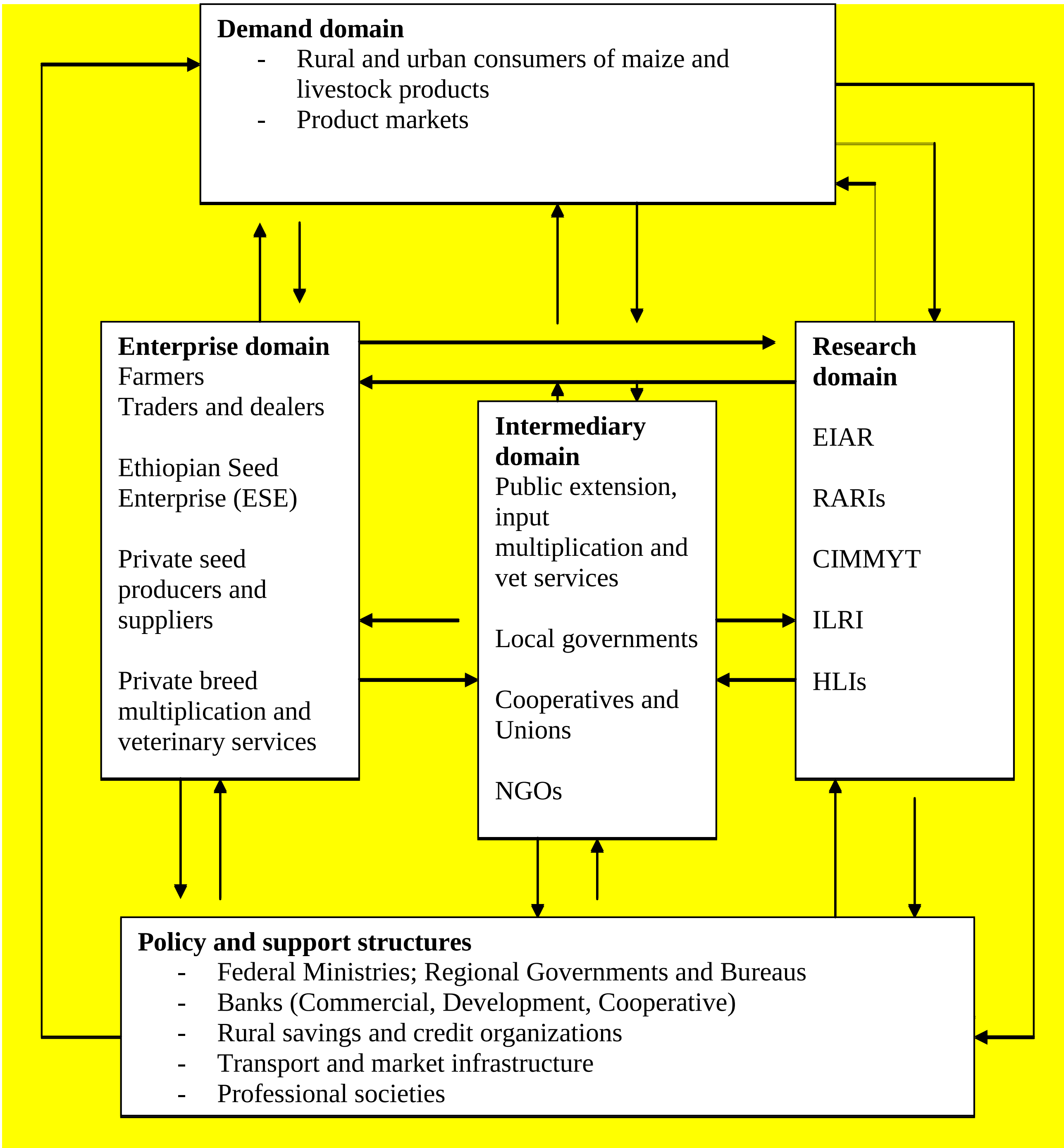

Figure 10. Schematic presentation of the maize – livestock innovation system from a national perspective.

Table 36. Key actors and their summarized roles in the research domain from a national perspective.

Actor	Role
EIAR	National research coordination; conducts research on both livestock and maize; facilitates professional networking
RARIs	Regional research coordination; conduct research on regional issues of agriculture; sources of germplasm (breeder maize seeds)
CIMMYT	Undertake maize research; funding national and regional maize research programs; capacity building; facilitates professional networking
ILRI	Conducting research on livestock and related issues; supply of forage germplasm for multiplication and further research; funding livestock related research agendas; capacity building
HLIs	Training and research; sources of germplasm (breeder maize seeds)

From the international sub-domain actors identified include the International Maize and Wheat Improvement Center (CIMMYT) and the International Livestock Research Institute (ILRI). CIMMYT plays an essential role in Ethiopia's maize research endeavors through technical backstopping, germplasm exchange, financial support and capacity building. ILRI plays an important role in livestock research and development efforts of the country through technical support, financial support, germplasm (forage) exchange and training.

Human resource instability in the national research domain affects the innovation process and the competence to solve problems. The Ethiopian government both at federal and regional levels has been trying to upgrade the technical capacity of the agricultural research system through funding from national and international sources. Agricultural researchers and university teachers sent for training tend to look for jobs outside of the system after getting their degrees. Government efforts to stop that by implementing binding legal frameworks have not changed the trend. In order to stop the loss of educated researchers and teachers an attractive remuneration package in relation to the cost of living and other social demands needs to be implemented. There have been efforts towards that end. For example, the pay rates for university teachers and agricultural researchers have been readjusted and increased. Nonetheless, those rates have not been considered enough by most professionals owing to the recurrent high inflation rate and consequent increase in the cost of living. Moreover, the disappointment of university teachers and agricultural researchers also stems from the perception that the rate of pay for expatriate staff (in higher learning institutes particularly) who are generally judged as less inclined to get engaged in national problem solving efforts, is far better than that for local staff. This creates a sense of dissatisfaction and is a disincentive to take new roles in the innovation system.

The maize research system is also blamed for not being responsive to the demand side as a result of a lengthy variety release mechanism and insufficient supply of breeder and foundation seeds to be multiplied. The research has been led in the traditional way of "*we know the best for the farmer*" style for decades. Reflections of that style are still apparent. Many researchers continued to identify researchable issues by themselves. The habit of involving the farmers in the research problem identification process is haphazard. Because researchers understand that working with farmers is an important way of doing research, the answer to the question of if they collaborate with farmers in the process of problem identification is predominantly 'yes'. However, evidence from the current assessment reveals that this only occurs in a few cases. Staff promotion requirements do not encourage researchers to work with farmers since they are required only to publish in peer reviewed journals which makes them overlook specific and impact oriented researchable issues.

What is critically missing in the research component is the habit of doing things together in order to generate technologies that could alleviate the socio- economic problems of poor farmers. This is mainly reflected between the crops and livestock units (Directorates) of EIAR. There is an understanding of the need to work together at a conceptual level. There has been a history of involving animal scientists (nutritionists) in the process of technology generation in teff and barley programs. However, even there, the evaluation of genotypes for use for livestock feeding focused only on biomass production by considering harvest indices which are not necessarily indicative of their potential utility as livestock feed. Maize breeders strongly agree on the need to involve animal nutritionists in the processes of maize technology generation when targeting for the mixed crop-livestock system. They condemn the earlier views reflected by some scientists that biomass production is a bad trait. However, despite available evidence (Adugna, 2002; Devendra and Pezo, 2004) about the possibility of combining grain and feed traits, there are still scientists who have a resistive notion to the suggested breeding strategy of combining food and feed traits. Instead of trying to combine grain and feed traits, which they think has little effect on availability and quality of feed from maize production, they advocate for agronomic manipulations such as rate of fertilization and planting density.

4.4.1.1.2. The enterprise domain

The enterprise domain includes farmers, traders and dealers of maize grain and inputs; maize seed producers and suppliers; and private breed multiplication and veterinary services. The Ethiopian Grain Trade Agency, government-owned, is an important actor in maize grain trade in the country.

The Ethiopian Seed Enterprise (ESE), which operates as a state-owned enterprise under MoARD, is responsible for the production and distribution of improved maize seed, among others, by receiving varieties that are released from the research system in the form of breeder seeds. Its internal organizational structure includes; seed production technology and extension, quality control, and seed marketing departments. It produces seeds on its own farms and obtains more from private companies produced on contractual basis. However, the maize seed system has been suffering from large shortfalls in relation to the magnitude of demand. For example, Dawit *et al*. (2007) reported only a 53% success rate in terms of the seed demand observed in the 2004/2005 cropping year. In order to improve the scenario, increasing the volume of seed production would play a key role. To this end, the involvement of more private companies in addition to the efforts that have been made by ESE is imperative. In this regard, Kenya’s experience (Odame *et al*., 2008) where the involvement of private companies in hybrid seed production boosted the supply of improved maize seed could be an important lesson to learn from. Nonetheless, the involvement of the private sector in maize seed production, despite the observed little increases in the past years (Dawit *et al*., 2007), has been limited. This is due, among other factors, to the fact that the processes of seed production are sensitive if they are to meet the national standards for certification. Professional and material requirements must be met if certification of the seeds is desired. As compared to other cereals, maize seed production procedures and requirements are believed to be less stringent. There is a complaint from the ESE side that most investors who intend to engage in seed production are reluctant to recruit professionals with the demanded skills due to their intent of reducing production costs. Even those who are willing to recruit the professionals face shortages since many professionals do not want to join the private sector for job security reasons unless the remuneration packages are attractive. Another problem is that companies which have been producing maize seed reported shortage of land and germplasm for increasing the scale and/or volume of their seed production.

In addition to the reported shortage and delay in input supply and high costs of inputs are known to be important bottlenecks in maize technology adoption. High input costs arise from the nature of the marketing system. Maize seeds produced by ESE and private firms are first collected in central stores and then redistributed to cooperatives and then to farmers. This long process escalates the cost of seed due to increased transaction costs. To this connection, improving rural road networking and decentralization of the maize seed production and supply system with stringent and workable regulatory and legal frameworks on quality deem necessary to ensure timely supply and reduced cost of inputs.

The extent of private sector involvement in the area of livestock input production and supply is very marginal except with respect to veterinary drug prescription and marketing. From the key informant interviews with people from the federal MoARD, it was understood that investors who were licensed for multiplying /breeding animals taking land and other facilities (loan), make a shift to other businesses like growing crops maintaining their names only in spite of the extent of the demand for their products. This is ascribed to large volume of initial investment requirement, slow rate of capital turnover due to the nature of livestock enterprises, and lack of breed and other related services. In this regard, availing loan facilities with special provisions for livestock projects, like giving more interest-free time, is desirable.

Moreover, regular inspections and legal enforcements are necessary to check project implementation and stop violations.

4.4.1.1.3. The intermediary domain

The most important actor in the intermediary domain is the public extension service. It is the ‘motor and brake’ in the whole system. Spearheaded by the Ministry of Agriculture and Rural Development (MoARD) and District Offices at the lowest administrative level, it coordinates the provision of a wide range of production inputs, extension, marketing, livestock health and regulatory services. Input demand assessment is one of the key roles of the public extension service.

The other important actors in this domain are Cooperatives and Cooperative Unions, the main role of which is transaction of both input and output. Both local and international NGOs have an important role in giving material and financial support to Cooperatives, Unions and individual farmers. NGOs like World Vision and Agri-service Ethiopia are involved in this domain by helping farmers produce maize seeds. The NGO which has been acclaimed for the successes it helped in the area of maize extension is Sasakawa Global-2000 which extended its activities to a farm level being involved in maize technology popularization and seed production and supply.

There is a concern among professionals that the transfer of livestock production techniques to farmers by extension services in developing countries has been neglected by both policy makers and researchers due to the marginal position of livestock extension (Morton and Wilson, 2000). Though the agricultural development policy of Ethiopia gives reasonably equal emphasis to both sub-sectors its implementation is dictated more by the production of enough grain in an effort to terminate the cycle of starvation. This resulted in a skewed focus towards crop production. Maize being one of the dominant cereal crops in Ethiopia, has received more attention than livestock production. The agricultural extension system is blamed for being tied to the conventional top-down approach which is not participatory and learning based. The extension system needs to be demand driven, inclusive (of the relevant actors), learning based and targeted at bringing about innovations. To this end, an appropriate and equitable strategy to capacitate the different components of the system (in terms of skill, resource, empowerment, etc.) needs to be designed and implemented.

4.4.1.1.4. The policy and support structure domain

Ethiopia, being among the slowest developing countries in the world (UNDP, 2009), is trying to pull itself out of that state by making efforts to bring about accelerated economic development. The focal economic policy known as Agricultural Development Led Industrialization (ADLI) puts the role of agricultural development as instrumental to foster economic growth through its contribution to food security and industrial transformation. The policy anticipates economic growth focusing on improving the performance of the agriculture sector. Consequently, promotion of agricultural innovation through generation and adaptation of new technologies received due emphasis. Allocation of a sizeable volume of public finance from the country's GDP to agricultural research and extension unlike other developing countries (Byerlee *et al*., 2007) is indicative of the magnitude of the policy focus on agriculture. Establishment of agriculturally-oriented Technical and Vocational Education Training (TVET) colleges for the training of Development Agents (DAs), and establishment of *kebele* level Farmers' Training Centers (FTCs) are important policy outcomes for capacitating the agricultural sector. Strengthening the credit system to support the extension through rural financing has also received attention.

The federal Ministry of Agriculture and Rural Development (MoARD) provides policy and strategy support to regional Bureaus of Agriculture and Rural Development. It licenses and regulates national input production and supply systems. Regional State councils formulate region specific policies, allocate budget for research and development activities, and give political leadership towards an effective implementation of planned activities according to national and regional policies and strategies. The Ministry of Finance and Economic Development and the regional counterparts allocate and regulate budget use by public organizations, and license and coordinate activities of NGOs. The role of the National Bank of Ethiopia as an actor responsible to formulate rural financial service regulations and licensing is also important.

Key actors in the support structure (Table 37) include Banks (National, Commercial, Development and Cooperative), rural savings and credit organizations, professional societies, and rural roads. The National Bank of Ethiopia serves as the main source of foreign currency for international purchase of inputs. Others (Commercial Bank of Ethiopia, Development Bank of Ethiopia and Cooperatives Bank of Oromia) are important sources of loans for small to large scale investments like input production and supply. However, banks require collateral for rendering loan and the process of endorsing funding requests are reportedly bureaucratic.

Table 37. Key actors and their roles in the support structure

Actor	Role
Banks (National, Commercial, Development, Cooperatives)	Source of hard currency for international input purchases; loans for private and public input producers and suppliers, and cooperatives
Rural credit and savings organizations	Credit and savings services
Professional societies	Knowledge sources
Rural roads authorities	Construction/rehabilitation of rural roads

Professional societies relevant to the topic include Ethiopian Society of Animal Production (ESAP), Crop Science Society of Ethiopia (CSSE) and Ethiopian Veterinary Association (EVA) and Agricultural Economics Society of Ethiopia (AESE). Professional societies are crucial players in the innovation system by serving as knowledge sources and as media for professional and policy debates. However, there are observed difficulties; firstly, they do not have the experience of discussing common agricultural issues jointly, and secondly, except publishing articles in their various organs, they have a very limited, if not nonexistent, experience of opening policy dialogues on agreed common agendas. Therefore, facilitating easy access to their publications and organizing more discussion platforms to inform and/or policy making are desirable.

Rural roads authorities that are under the direct management of regional governments are responsible for the construction and/or rehabilitation of rural roads to facilitate marketing. However, poor road networking has been reported to be among the major constraints in maize grain marketing (Dereje and Abdissa, 2001) and input supply.

4.4.1.1.5. Product markets

An important component of the national maize-livestock innovation system considered as a subset of the 'demand domain' is product markets. Market is an important driver of agricultural innovation. In the context of smallholder maize-livestock farmers where maize and livestock products are the main cash sources, product markets play an essential role in determining farmers' innovative behaviour and capacity. Therefore, analyses of the product market situations are presented in the following sub-sections.

4.4.1.1.5.1. The livestock product market

Though livestock production in Ethiopia is of subsistence type with little market orientation (Ayele *et al*., 2003; Azage *et al*., 2006), smallholder farmers in the mixed crop-livestock production system obtain cash income from the sale of livestock products, of which live animal marketing is the major one. The live animals that are sold by producers include slaughter types (small ruminants - largely males, culled oxen and barren cows) and replacement (for draught and breeding) types (young bulls, heifers, goats and sheep). Replacement types are mainly transacted between farmers at farm gate or at local/primary markets. The market chain discussed here only focuses on the market of slaughter type animals as depicted in Figure 11.

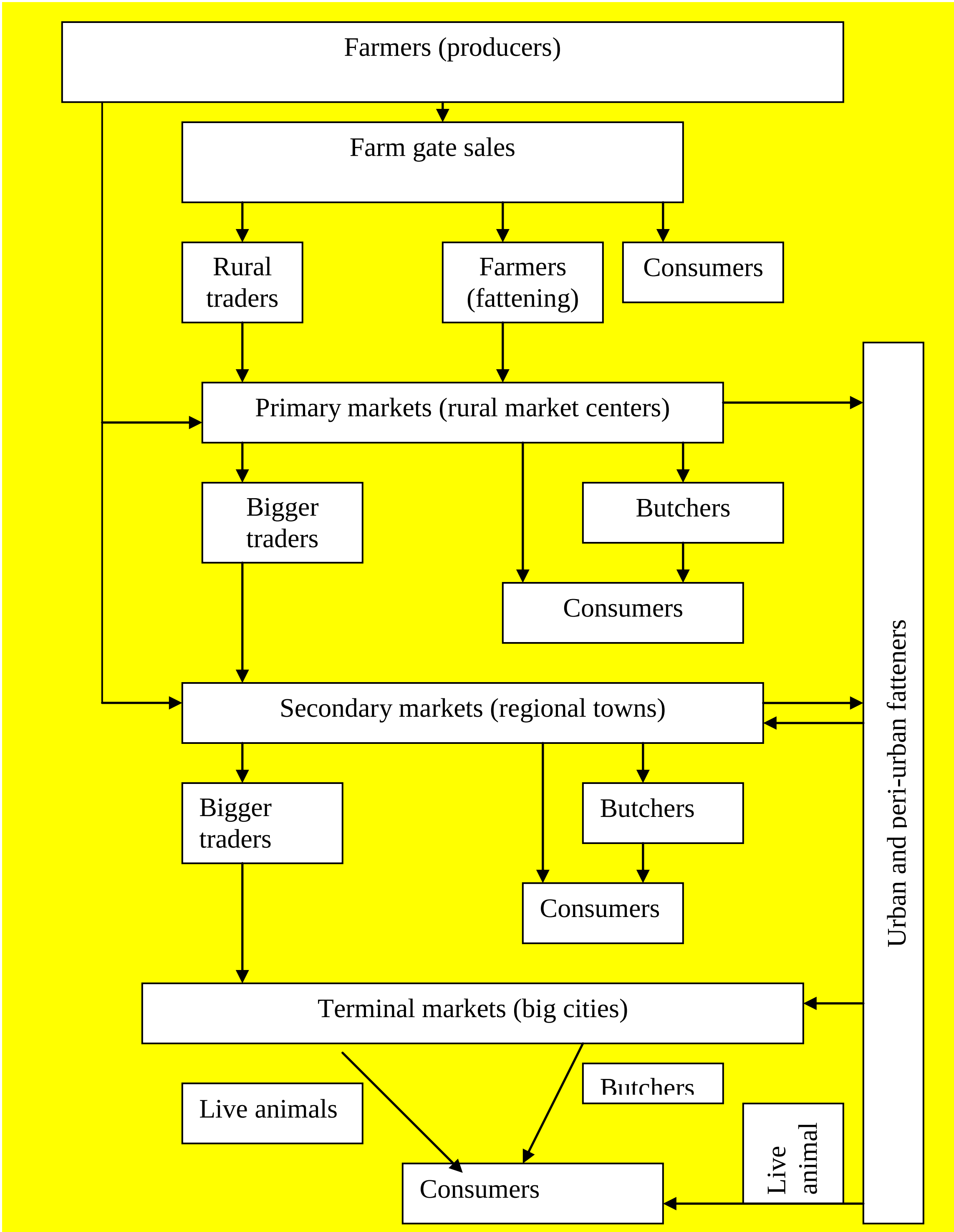

Figure 11. Typical market chain for slaughter type livestock raised in the maize - livestock system.

Livestock producers or farmers may sell their animals at farm-gate (very minimal volume) or supply to the primary market. Buyers of animals at farm-gate include local traders, other farmers (for fattening and re-selling) and local consumers (individual or groups of farmers) for slaughter during festive occasions and other social events. Consumption at this level is minimal. Traders after the primary market are the major suppliers of animals all through the terminal market. The terminal markets at the big cities are sources of meat for consumers through butchers that receive and process meat from abattoirs. Urban and peri-urban fatteners are also important actors in the chain whose role starts mainly at the primary markets as buyers. At the secondary markets, the fatteners are involved in a two-way transaction – may supply fattened animals to butchers/consumers and may also buy animals for fattening.

Though export abattoirs obtain animals largely from the pastoralist production system, an important share (particularly of small ruminants) comes from the mixed crop-livestock system. However, recurrent bans imposed by the importing countries due to disease problems consequently impact livestock prices. In general, livestock marketing faces several problems of which the major ones include; inadequate market places, shortage of good condition animals, shortage of stock supply for fattening, lack of animal transportation facilities, lack of market information and low price due to poor body conditions. Moreover, seasonality of livestock prices (with peaks during festive periods) and insufficiency in the supply of replacement stock are constraining producers to respond to the demand.

4.4.1.1.5.2. The maize grain market

The maize grain flow begins with the farmer who, after harvest, decides how much to store for household consumption, seed and payment in kind and sells the remaining grain (market supply) to a trader or another consumer in order to settle debts and contributions, taxes and to purchase other consumer goods. The hierarchy of the food grain marketing system from small rural markets at the top to the terminal urban markets at the bottom consists of a number of different steps and types of grain traders. Figure 12 illustrates how the various participants are linked to the complex network of marketing channels for maize grain. Producers of maize sell grain to three potential recipients: local consumers, local traders/village collectors and cooperatives. Local traders sell to wholesalers from who retailers and *kebele* shops buy maize for supplying to urban consumers. Cooperatives sell to their unions from which the Ethiopian

Grain Trade Agency collects. The federal Disaster Prevention and Preparedness Commission buys much of the supplied volume and *kebele* shops also come into play at this point for distributing to urban consumers. The involvement of flour mills in the maize grain market chain is almost nonexistent except one company in Bahir Dar city which processes maize into flour and extracts oil from it.

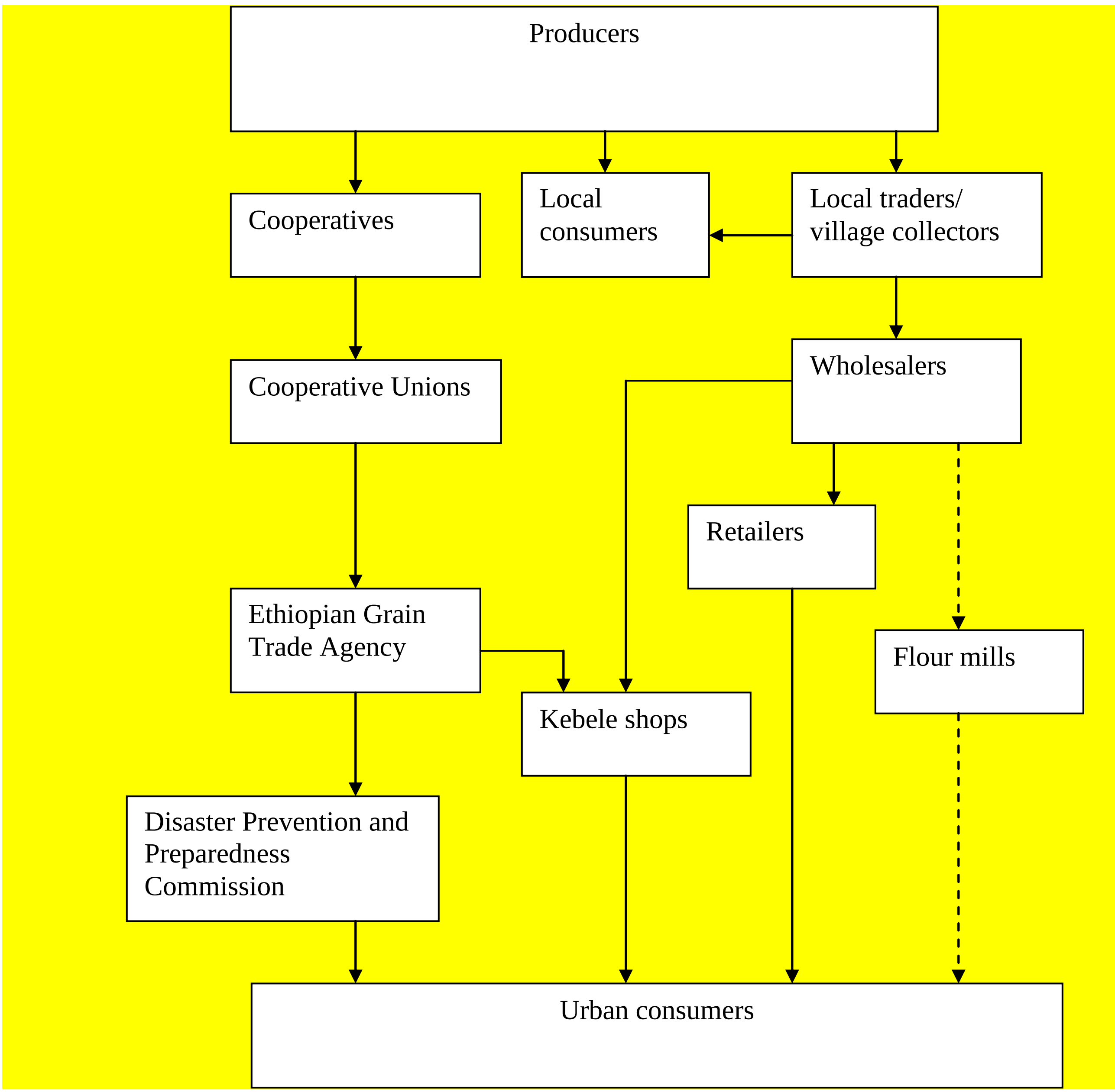

Figure 12. The maize grain market chain.

The maize grain market is characterized by seasonal and yearly price fluctuations. Right after the harvest season, maize grain prices are lower because of a relatively large supply. However, farmers are obliged to sell grains at an early time after the harvest due to storage problems and early request for tax and debt payments. Market information and transport problems are also limiting factors to farmers for not selling at a better price. As maize is the most susceptible of the cereals to post harvest loss (EEA/EEPRI, 2006), research and extension support in terms of generating and disseminating affordable storage technologies could play an important role in assisting farmers to store grains. Maize marketing is also constrained by transportation problems as a result of poor road networks. The predominantly used means of grain transport to market are pack animals and human beings. This affects the volume of grain that can be transported to market in search of better prices. Farmers' Cooperatives buy maize from their members at a 10 % premium price and sell to Cooperative Unions after storing for sometime. However, this practice does not favor those farmers who are not members of the Cooperatives. Even those who are members do not have a sense of ownership to their cooperatives as a result of lack of transparency, and irregularity and usually absence of dividend sharing. Improving the performance of the cooperatives in the maize grain market would play a crucial role to increase the farmers' share by reducing the number of middlemen in the maize grain market chain. Moreover, improving the road networking increases the farmers' share of income from maize grain since more vehicles are attracted and this creates competition between local traders opening chances for better prices.

4.4.1.2. Incentives, institutions, and habits and practices

Established attitudes, habits and reward systems are critical components of a successful innovation system by motivating actors to take new roles to respond to the needs of existing and new clients. The nationally operational and formal mechanism of interaction among actors in the system is the Research and Extension Advisory Council (REAC). This Council has Zonal, Regional and National structures of which the Zonal is the most active. This is a forum where agricultural research and extension, development plans and activities are discussed and evaluated. The forum was set up to be "inclusive" of actors in the system focusing mainly on actors with national mandate: research centers (national and regional), higher learning institutions, NGOs, Bureaus and District Offices of Agriculture, public and private input producing and supplying agents. Inclusiveness is important in innovation since it is a source of demand and non-market mechanisms such as collaboration and linkage are important even where market mechanisms are developed (Hall *et al*., 2006). The level of inclusiveness of this mechanism is questionable. Here, farmers are represented in very small numbers. The forum targets at diagnosing farmers' issues through discussions with them. However, there are claims that the level of participation by farmers is limited by the size of representation and due to communication barrier as the forum tends to be conducted in technical language that is not always understood by the farmers. Joint project appraisal schemes, joint supervision of graduate research and co-publication, participation of professionals in student evaluation processes are important learning processes that are practiced among actors in the research domain. A summary of the institutional arrangements and key issues in terms of interaction and learning among key actors in the national maize – livestock innovation system is presented in Table 38.

Table 38. Summary of institutional arrangements and key issues in terms of interaction and learning among key actors in the national maize – livestock innovation system

Institutional arrangement	Key issues
➢ The research domain • After center level review, EIAR holds annual review programs involving actors from national and international research institutes, MoARD, public and private input producers and suppliers • EIAR, its national and international research and NGO partners facilitate professional networking by sponsoring society meetings and publication of proceedings for wider use • EIAR and partners conduct on-farm demonstrations, organize field days and coordinate variety release processes, write reports	• The level of inclusiveness of actors is erratic • Lack of being interdisciplinary • International institutes incline to be involved more in issues that have international significance • Organizing joint forums for professional societies limited • Lengthy variety release mechanism • The research system has been conditioned to be responsible for not more than these activities and its interaction with end users very limited • Irregularity and sometimes absence of reporting the status and results of financed research programs to the coordinating institute • Focus on knowledge/technology and not on innovation
➢ The enterprise domain • The Ethiopian Seed Enterprise (ESE) under MoARD participates in variety release processes, farmers field days; involved in maize seed quality certification • Receives pooled seed demand and supplies basic seeds to private seed companies; buys seeds from them at a 10% premium price • Private seed, livestock breed multiplication and veterinary service givers licensed and regulated by MoARD	• ESE does not have a direct contact with farmers • Private seed and breed multipliers are not mandated to supply inputs to farmers in their localities and have very little interactions with the end users • Participation of the private sector actors in knowledge sharing processes is very marginal

Table 38 (continued)

Institutional arrangement	Key issues
➢ **The intermediary domain** • The federal MoARD, regional counterparts and district offices coordinate the extension service, input production and supply, rural financial services, veterinary services, conduct input demand assessment • The public extension service is the most important actor in relation to its close interaction with farmers • Local governments give resources and political leadership towards effective implementation of planned activities; coordinate and supervise activities of cooperatives and their unions • NGOs provide resources (financial and material) and training to cooperatives, rural financial organizations and individual farmers	• The interactions between actors in this domain and outside usually take the form of routine bureaucratic exposures • NGOs have limited personnel and face confusions with the district offices in resource and responsibility sharing • NGOs have limited interactions with the public research except rare consultations
➢ **The policy and support structures domain** • Federal ministries and their regional counterparts, and regional governments give policy directions, license and regulate the activities of NGO and private actors • Rural roads authorities under regional governments are responsible for rural road rehabilitation and construction	• Confusions in interaction and responsibilities between federal and regional issues • Individual components that belong to the domain are not well integrated

There are no functional and meaningful mechanisms of interaction between actors in the maize-livestock innovation system. Moreover, the actors have capacity limitations to execute their roles up to the level and quality that the system requires for being effective, efficient and sustainable. The overall picture of the maize-livestock innovation system is tied with the conventional top-down approach which is not participatory and learning based. There are no established and functional feedback mechanisms and interactions. The interactions are dictated by personal interests and confused by resource competition. Even there, the interactions are not trust worthy. This is mainly reflected by the situation that exists between the extension service and the end users. As a whole, an institutional innovation and building the culture of working together to bring about technological change is required. There has to be a shift of mind set in terms of the way the organizations and professionals have been behaving in order to bring a change in the performance of the agriculture sector. The poor linkage and interaction mechanisms need to be improved by establishing new and/or activating the existing linkage and interaction mechanisms with clear mandates to each actor

4.4.2. The cases of Awassa, Bako and Ambo areas

The maize –livestock innovation systems in the study areas are generally the reflection of the national system. The actors, their roles and linkages identified in the case study areas are summarized in Tables 39, 40 and 41. By virtue of its location in the vicinity of the regional capital of the Southern Nations, Nationalities and Peoples Regional State, Awassa area has more NGO actors than the Ambo and Bako areas. The list of NGOs operating in Awassa area which are directly or indirectly linked to maize and/or livestock issues includes Meserete Kiristos Church, World Vision Ethiopia, Mekaneyesu Church, Goal Ethiopia, Plan Ethiopia, Self Help International, and Aden Ethiopia. Their overall roles include relief and input supply, credit and savings, revolving fund provision for Cooperative Unions, and soil conservation and reforestation activities. The NGOs in Ambo are USAID and World Vision Ethiopia where USAID is engaged in the supply of small ruminants for women farmers through Ambo University; and World Vision Ethiopia finances Wisdom Microfinance Institute for credit service given to rural and urban low-income groups. The only NGO which operates in Bako area is the Mekaneyesus Church involved in the provision of relief service and financial support for input purchase to individual farmers.

The engagements by NGOs are usually shaped at higher levels (Ministries and/or Regional Bureaus) without community level participation and proper consultations. The NGOs are required by the local governments to justify the potential contribution of their planned activities/projects towards improving the livelihoods of the target farmer groups. In Awassa, most NGOs are inclined to get engaged in 'high value' crops such as haricot and Soya beans. By the very reason that maize is not considered to be one of the high value crops that the NGOs are interested in promoting, their involvement is very limited. Hence, promotion by local and federal governments towards a better engagement of processors of maize grain would attract more NGOs to assist farmers for continued involvement in maize production.

Table 39. Key public sector actors, their roles and linkages in the case study areas.

Actors	Operating area	Role	Linkage with
Regional Bureaus and District Offices	All	Extension service, input demand assessment and facilitating input supply	Farmers, NGOs, Cooperatives, Microfinance institutions
Awassa Agricultural Research Center	Awassa	Conducts research- both on-station and on-farm; consultations on improved agricultural technologies	EIAR, Regional Bureaus and District Offices; farmers
Hawassa University	Awassa	Research and training	Awassa Agri. Research Center, farmers, NGOs, Regional Governments and Bureaus
Ambo Agricultural Research Center	Ambo	Conducts on-farm trials; supply basic and certified seeds to farmers and seed multipliers; train farmers on new technologies through field days and workshops	Regional Bureaus, District Offices, farmers, seed multipliers, EIAR, CIMMYT
Ambo University	Ambo	Research and training; heifer distribution for women groups; distribution of hay box brooder; beef fattening packages	Regional Bureaus, District Offices, farmers, USAID, EIAR
Bako Agricultural Research Center	Bako	Conducts on-farm trial; supplies basic and certified seeds to farmers and seed multipliers; trains farmers on new technologies through field days and workshops	Regional Bureaus, District Offices; Regional Governments, EIAR, CIMMYT, ILRI

Table 40. Key NGO and CBO actors, their roles and linkages in the case study areas

Actors	Operating area	Role	Linkage with
NGOs • World Vision Ethiopia	Awassa and Ambo	Relief and input supply; credit and savings; revolving fund provision for Cooperatives and Unions	Regional Bureaus, District Offices, farmers and their cooperatives
• Mekaneyesus Church	All		
• Goal Ethiopia, • Plan Ethiopia • Self Help International	Awassa		
• USAID	Ambo		Regional Bureaus, District Offices, farmers, Ambo University, Wisdom Micro Finance
CBOs • Sidama Chalala Rural Savings and Credit Union	Awassa	Credit and savings	Farmers, Regional Bureaus, District Offices , Sidama Elto Farmers' Cooperatives Union
• Sidama Elto Farmers' Cooperatives Union	Awassa	Supplies inputs to member cooperatives; credit services; purchases agricultural products from members	Member cooperatives, Regional Bureaus, District Offices, farmers, Sidama Chalala Rural Savings and Credit Union
• Ambo Farmers' Cooperative Union	Ambo	Supplies inputs to member cooperatives; credit services; purchases agricultural products from members	Member cooperatives, Regional Bureaus, District Offices, farmers,
• Cooperatives	All	Input supply	Farmers, District Offices, Unions

Table 41. Key private sector actors, their roles and linkages in the case study areas

Actor	Area	Role	Linkage with
Agricultural Inputs Supply Enterprise, Southern Branch	Awassa	Supplies inputs – fertilizer, vegetable seeds, herbicides and pesticides and vet drugs	Cooperatives, District Offices
Gaddisa Gobena Commercial Farm Products Private Enterprise (Plc)	Ambo	Production and supply of improved maize seeds; production and distribution of crossbred heifers	Farmers, Regional Governments
Wisdom Microfinance Institute	Ambo	Savings and credit service for low-income groups (rural and urban)	Farmers, World Vision Ethiopia for funding and partnerships, District Offices
Anno Agro-Industry Share Company	Bako	Production and supply of improved maize seeds; production and distribution of crossbred heifers	Farmers, Regional Governments, Bako Research Center

The role of credit service provision is played predominantly by Cooperatives and their Unions. Cooperatives and Unions are engaged in market transactions (both input and output) through the financial support from rural finance institutes, NGOs and members. The NGOs interact with cooperatives through regional and district level offices. Private sector actors have very limited interactions with farmers. Cooperatives are the major suppliers of maize production inputs and supply these inputs on credit. Farmers are required to pay 35 % of the total loan (interest included) as a down payment and sign an agreement to pay the rest of the loan in the same cropping year. If any farmer fails to do that, he/she will not be entitled to buy inputs on credit any more in addition to being subjected to the judiciary to materialize the payment immediately by selling available property and/or contracting out land. Most of the sample farmers in the Awassa district do not buy inputs from the cooperatives on credit due to failure to pay earlier incurred debts. The request for a 35% down payment at a time when the cash capacity of farmers is seriously constrained is a burden which causes, in several cases, reluctance of the farmers to use the recommended rates of inputs. The credit services are generally rated by farmers as problematic. Farmers complained about the credit services they receive as being highly bureaucratic, high interest rates, shortage of money and problems with debt collection. The private credit companies require collateral and do not have the necessary personnel to facilitate training on how to make effective use of the loans they offer to farmers. As a result of this, there are repeated concerns by farmers, in Ambo for example, where farmers often fail to pay their debts as a result of the use of loans for less productive engagements.

The shortage in the supply of maize production inputs through the government facilitated channel makes farmers purchase inputs from private dealers. However, farmers complain about quality problems of inputs purchased from the private dealers. Some dealers cheat farmers by selling maize grain filled in sacks that are with marks of certified seed producers. For example, a total maize crop failure in one growing season was reported in Awassa area due to this mischief. Reducing the weight of the sacks previously checked and supplied was also reported. Farmers have less awareness about quality of fertilizer. However, caked urea was at one time supplied to farmers. These problems need to be corrected by implementing stronger inspection and regulatory mechanisms by responsible governing bodies. Otherwise, this situation will de-motivate farmers from using improved maize technologies as a result of loss of confidence in the system.

The involvement of Ambo University and Hawassa University in the maize-livestock innovation system is through their roles in training (farmer groups, cooperatives) and research through practical attachments, graduate programs and own staff involvements. For example, Ambo University's graduate program collaborates with Ambo Research Center making its students to do research on thematic areas of the Center's mandate. However, there are complaints by researchers about limited availability of funds. As a result, the involvement of the higher learning institutions in the innovation system is dictated by the funding opportunities. If their request for funding is to the federal research system, they participate in the proposal appraisal processes. Their research engagement seems donor driven (donors being national government and international) and highly influenced by professional interests. The experience of the College of Agriculture of the Hawassa University in evaluating maize genotypes for stover quality could be exemplary of inter-disciplinary cooperation between maize breeders and animal nutritionists.

There are no meaningful interactions among actors in terms of knowledge sharing. Almost all of the interactions observed in the study areas take the form of routine bureaucratic exposures. A generalized pattern of interaction observed in the study areas is illustrated in Figure 13.

Due to their long history of participation in maize research, Bako and Awassa Research Centers are better off in terms of experience and skill as compared to Ambo Research Center, the experience of which is limited because of its recent engagement in maize breeding programs for the highland ecologies. The other difference is the staffing and funding sources where Bako and Awassa Research Centers seem to be at a better state since they host maize programs with both regional and national mandates. With the exception of the Bako Research Center, which is recognized as one of the centers where livestock research is strong, livestock research programs are nonexistent at Ambo Research Center and the livestock programs at the Awassa Research Center are not strong.

Private sector actors which are involved in maize seed production are not allowed to supply seeds directly to local farmers. However, Anno Agro-industry Share Company in Bako area and Gaddisa Gobena Agri-Business Company in Ambo supply maize seeds to farmers in return for labor contribution during maize harvest. This is also practiced with Bako research center. However, farmers complain about the quality of seed they obtain through this arrangement. This may be due to the likelihood that the companies distribute maize seeds which failed to meet standards to enter the national input market. Because this is an unofficial operation based on the understanding between the companies and the farmers, there is no way to formally appeal to the regulatory and judiciary processes for the misbehavior committed.

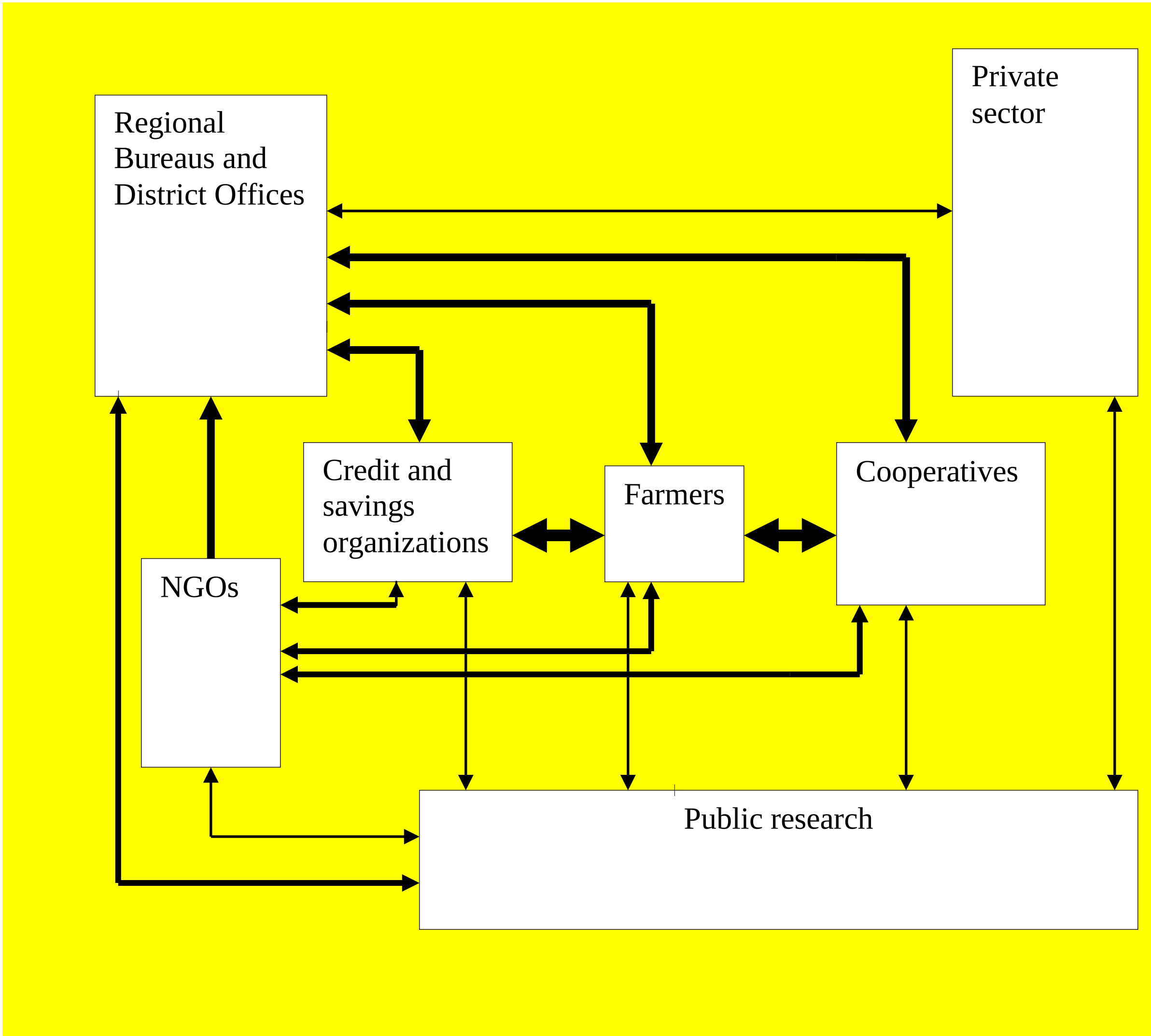

Figure 13. Observed pattern of interaction among key actors in the study areas.
Thickness of the lines (___) indicates the relative strength of interaction between actors.

As a matter of national policy, each peasant association (PA) or rural *kebel* is made to have three junior agricultural professionals as Development Agents (DAs) mandated to serve animal production, crop production and natural resource issues. Farmers training centers (FTCs) are also built in most of the PAs. However, the proportion of farmers who have received/have participated in training on improved agricultural practices is low. Development agents tend to reside in townships and spend more of their time engaged in continuing education in areas other than agriculture. The extent of their visits to farmers' fields even during the cropping season is also low. Due to the tradition of the extension service nationwide, more frequent consultations and visits are made with the so-called 'model farmers'. The DAs visits are generally confined to those 'model farmers' because it is from those that important reports about their performances are collected. Most farmers consider DAs as mere political figures instead of recognizing them as development partners. Sometimes the reports coming from DAs on their achievements have credibility problems sensed even by farmers themselves. This destroys the trust that has to exist between farmers and the extension service. Moreover, DAs' activities are dominated by other instructions coming from the top than their role as sources of knowledge and capacity building. Offering on-job trainings and facilitating better living conditions to DAs could help them upgrade their capacity and motivate them to serve the system better.

Despite the existence of a huge demand for improved maize and livestock technologies in all of the study sites, the extents of supply and demonstrations have been very limited discouraging the users for the demand. The competency of the actors in all the study areas is generally rated "weak" but weaker in Ambo.

5. SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. Summary and Conclusion

Agriculture is the backbone of Ethiopia's economy where the mixed crop-livestock system is the most dominant land use practice. Maize is one of the most important commodity crops most of the production of which comes from the mixed crop-livestock system where there is a great deal of interdependence between maize and livestock production. Despite the long history of maize research and extension efforts in Ethiopia, the rate of adoption of maize technologies has been the least even by East African standards. Researchers acclaim the critical importance of understanding mixed crop-livestock systems properly in order to devise appropriate technology transfers and institutional reforms for poverty alleviation, food security and sustainable resource management. The objectives of the study were (i) to assess farmers' practices in the use of maize stover for livestock feeding and analyze influence of variety on yield and quality of the stover; (ii) to analyze constraints to the linkage between the maize and livestock subsystems; (iv) to assess factors influencing farmers' preferences to improved maize varieties; and (iv) to describe and understand the maize-livestock innovation systems at a national level and in selected areas. The study included three levels of analysis, namely the macro, *meso* and micro levels. The macro level analysis focused on evaluating the national maize – livestock innovation system where key actors, their roles and competencies, their habits and practices, and linkages and interactions were analyzed through review of secondary sources and key informant interviews. The *meso* level emphasized on the analysis of the innovation systems in Awassa, Bako and Ambo areas, and the assessment of feeding practices and farmers' rankings of maize varieties through key informant interviews and focus group discussions. This level was carried out in three purposively selected districts in each of the study areas. Stover samples collected at green (*eshet)* and mature (dry) stages from on-farm demonstration plots were analyzed for their chemical composition (ash, N, NDF, ADF, ADL, IVOMD and ME). Household level data (the micro level) were collected in one randomly selected district (from those included in the *meso* level) from each of the areas which were Awassa, Bako Tibe and Ambo districts from Awassa, Bako and Ambo areas respectively. According to the principle of 'sample proportional to size', the number of sample farmers was 90 in Awassa, 120 in Bako and 140 in Ambo making a total sample size of 350 households. Analysis of factors that affect farmers' choice of varieties was done using the multinomial logit model. Descriptive statistics and ANOVA were also employed as analytical tools.

Livestock numbers and productivity have been severely constrained by shortage of feed in the study areas. As the sites are situated in the major maize belt, maize production supplies a significant portion of the feed for livestock. The use of maize stover for livestock feeding is more intense in Awassa area than in both Bako and Ambo areas due to larger household land ownership and more diverse crops grown that supply residues for feed in the latter. However, dry maize stover is not conserved in Bako and Ambo areas. Farmers who own livestock showed a great deal of interest to adopt dual purpose (food-feed) maize varieties. Significant varietal differences were observed in NDF and ADL contents of stovers from the studied maize varieties. However, varietal difference in grain yield was not significant.

The linkage between the maize and livestock subsystems towards an integrated maize-livestock production system has been constrained by several problems. These constraints affect resource flows between the two subsystems by constraining both or either. These included socio economic, biophysical and institutional constraints. Ever intensifying population pressure which influences the availability of land for maize production and grazing and large family size of households motivating farmers to cultivate more land dictated by the demand for enough grain are affecting the linkage. Feed shortage coupled with disease problems causes continuously declining livestock number and productivity constraining the contribution of livestock to the maize subsystem. Unbalanced research and extension focus between the maize and the livestock subsystems, difficulties in the process of technology popularization and inefficient and ineffective input, credit and veterinary services are the important institutional bottlenecks for integrating the maize and livestock subsystems to the level they could. Analysis of the factors that affect farmers' choice of maize varieties gave results with a possible implication that livestock owning farmers make a preference to a variety with better stover quality in addition to grain yield.

There are no functional and meaningful mechanisms of interaction between actors in the maize-livestock innovation system. Moreover, the actors have capacity limitations to execute their roles up to the level and quality that the system requires for being effective, efficient and sustainable. The overall picture of the maize-livestock innovation system is tied with the conventional top-down approach which is not participatory and learning based. There are no established and functional feedback mechanisms and interactions. The interactions are dictated by personal interests and confused by resource competition. Even there, the interactions are not trust worthy. This is mainly reflected by the situation that exists between the extension service and the end users.

The system suffers from shortages and high prices of inputs added to lack of timely supply. Lack of proper input demand assessment is also contributing to the scope of the problem. The inputs have to go long distances, first to be stored in the central supply stores and redistributed. This increases the cost of inputs as a result of increased transaction costs. There is a high government control over the input system. The involvements of private maize seed and livestock input producers and suppliers are very limited. The competency of the national agricultural system has been affected by staff instability. This requires putting an attractive remuneration package. The general picture of the innovation system in the case study areas is the reflection of the national system. Farmers in Awassa and Bako areas have a better maize related knowledge base than those in Ambo.

5.2. Recommendations

Though results of the current study gave indication about the possibility of manipulating feed related traits in the effort to breed and/or select for maize varieties that combine food and feed traits, and farmers are interested in adopting dual purpose maize varieties, the anticipated benefits cannot be realized unless the prevailing problems in the maize – livestock innovation system are rectified. It has to start from the inception of processes of technology generation up to its productive use by the end users. Therefore, the following key recommendations are forwarded:

- Actors in the agricultural research system should revise their staff promotion policies to motivate their staff to work on impact oriented pro-poor research relevant to national and/or regional contexts. The policies need to acknowledge and reward the contributions of researchers to scientific knowledge as well as to the innovation processes towards bringing local change required for sustainable social and economic development. In addition, there has to be a continued effort to change the mind-set of agricultural professionals about the need to collaborate with relevant actors in the innovation system.

- Continued capacity building efforts for all of the actors and promotion of trust worthy interactive learning processes for better technological uptake and responsiveness to the demands of end users are necessary.
- Decentralizing the input production and delivery systems is imperative to reduce costs and for a timely supply which needs to be supported by workable legal and regulatory frameworks on quality.
- Involvement of more private sector actors in the input production and supply should be encouraged. The credit/loan and banking systems require further strengthening along with efforts to alleviate the prevailing problems, which are more of capacity related (resource and managerial) to encourage better private actor involvements in the maize-livestock innovation system. Moreover, an insurance package needs to be put in place to motivate private actor engagements in activities with potential risks like input production (improved maize seeds and livestock breeds).
- The maize grain market system has to be supported by better road networking and affordable post-harvest (storage) technologies along with involvement of agro-processors of maize grain in order to help farmers fetch better grain prices.
- The tax and debt payment calendars need to be flexible with the intent of allowing farmers to sell their produces at a better price.
- All in all, an institutional innovation and building the culture of working together to bring about technological change is required. There has to be a shift of mind in terms of the way the organizations and professionals have been behaving in order to bring a change in the performance of the agriculture sector. The poor linkage and interaction mechanisms need to be improved by establishing new and/or activating the existing linkage and interaction mechanisms with clear mandates given to each actor.
- There is a need to institutionalize the 'innovation systems' perspective in planning and/or evaluating investments in agricultural (maize-livestock) research and extension.

5.3. Limitations of the study and scope for future work

This piece of work has generated valuable information and recommendations that would serve as a springboard for further research and/or for immediate implementation. However, it is hardly without limitations. In the attempt to make contrasts between maize varieties for grain and stover characteristics categorized into landraces, open pollinated varieties and hybrids, no enough landraces were included to build up the category. Therefore, the results of the comparison need to be cautiously considered. On the other hand, in the econometric analysis of the factors on household level variety preference, there is a fear that the precision with which the results have been reported might have suffered from small sample sizes. Moreover, the analysis of the maize-livestock innovation system took a broad and generic perspective as a form of national innovation systems analysis. Hence, a more specific intervention based analysis of the system incorporating emerging tools of analysis is suggested.

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REFERENCES

Abdissa Gemeda, Girma Aboma, Verkuijl, H. and Mwangi, W., 2001. Farmers' maize seed systems in western Oromia, Ethiopia. Mexico, D.F.. International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO). 32p.

Adesina, A. and Zinnah, M. 1993. Technology characteristics, farmers' perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural Economics* 9: 297-311.

Adugna Tolera, Sundstol, F. and Said, N.A. 1998. The effect of stage of maturity on yield and quality of maize grain and stover. *Animal Feed Science and Technology* 75:157-168

Adugna Tolera1, Berg, T. and Sundstol, F. 1999. The effect of variety on maize grain and crop residue yield and nutritive value of the stover. *Animal Feed Science and Technology* 79:165-177.

Adugna Tolera, 2002. Integrated food and feed production on small-holder mixed farms: Effect of early harvesting or variety on maize grain and stover yield and nutritive value of stover. pp.187-194. Proceedings of the second National Maize Workshop of Ethiopia. Addis Ababa, Ethiopia, 12- 16 November 2001. International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

Alemayehu Mengistu, 2004. Pasture And Forage Resources Profile Of Ethiopia, Addis Ababa EDM Printing Press, Addis Ababa, Ethiopia.80p.

Ayele Solomon, Assegid Workalemahu, Jabbar, M.A., Ahmed, M.M. and Belachew Hurissa, 2003. *Livestock marketing in Ethiopia: A review of structure, performance and development initiatives.* Socio-economics and Policy Research Working Paper 52. ILRI (International Livestock Research Institute), Nairobi, Kenya. 35p.

Azage Tegegne, Berhanu Gebremedhin and Hoekstra, D. 2006. Input supply system and services for market-oriented livestock production in Ethiopia. pp 1-19. Proceedings of the 14th Annual Conference of the Ethiopian Society for Animal Production (ESAP), September 5-7, 2006. Part I: Plenary Session. Addis Ababa Ethiopia.

Barnes, R.J., Dhanoa, M.S., Lister, S.J., 1989. Standard normal variate transformation and detrending of near infrared diffuse reflectance spectra. *Applied Spectroscopy* 43: 772-777.

Bastiaensen J., De Herdt T. and D'Exelle B., 2004. Poverty reduction as a local institutional process. *World Development* 33:979-993.

Belay Egigu, 1998. Ethiopian experiences on maize extension activities.pp.33-37. Proceedings of the Sixth Eastern and Southern Africa Regional Maize Conference. Addis

Ababa, Ethiopia, 21-25 September 1998. International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

Benti Tolessa, Kebede Mulatu, Lgesse Wolde, Mosisa Worku and Leta Tulu, 1996. Reflections on the successful achievements of hybrid maize breeding program in Ethiopia. pp.67-71. Proceedings of the fifth eastern and southern Africa regional maize Conference. Arusha, Tanzania, 3-7 June 1996. International Maize and Wheat Improvement Center (CIMMYT).

Berhanu Gebremedhin, Fernandez-Rivera S., Mohammed Hassena, Mwangi W. and Seid Ahmed. 2007a. Maize and livestock: Their inter-linked roles in meeting human needs in Ethiopia. Research Report 6. ILRI (International Livestock Research Institute), Nairobi, Kenya. 103 p.

Berhanu Gebremedhin, Hoekstra D. and Samson Jemaneh. 2007b. *Heading towards commercialization? The case of live animal market in Ethiopia.* Improving Productivity and Market Success (IPMS) of Ethiopian Farmers Project Working Paper 5. ILRI (International Livestock Research Institute), Nairobi, Kenya. 73p

Berhanu Taddese. 2009. Heterosis and combing abilities for yield, yield-related parameters and stover feed quality traits for food-feed in maize adapted to the mid altitude areas of Ethiopia. M.Sc Thesis submitted to the School of Graduate Studies, Haramaya University. 189p.

Byerlee D. and Heisey P.W., 1996. Past and potential impacts of maize research in sub-Saharan Africa: a critical assessment. *Food Policy* 21(3):255-277

Byerlee, D., Spielman, D. J, Dawit Alemu and Gautam, M. 2007. Policies to promote cereal intensification in Ethiopia: A review of evidence and experience. IFPRI Discussion Paper 00707.

Cameron, A.C. and Trivedi, P.K. 2005. Microeconometrics: methods and applications. Cambridge University Press. New York. 1034p.

Carlsson, B., Jacobson, S., Holmen, M. and Rickne, A., 2002. Innovation systems: analytical and methodological issues. *Research policy* 31: 233-245

Chilot Yirga and Hassan, R.M. 2008. Multinomial logit analysis of farmers' choice between short- and long-term soil fertility management practices in the highlands of Ethiopia. *Ethiopian Journal of Agricultural Economics* 7: 87 – 105.

CSA (Central Statistical Agency of Ethiopia). 1996. Agricultural sample survey report for 1995/1996. Addis Ababa, Ethiopia.

CSA. 2006. Agricultural sample survey report for 2005/2006. Addis Ababa, Ethiopia.

CSA. 2007. Report on human population. Addis Ababa, Ethiopia.

CSA. 2008. Agricultural sample survey report for 2007/2008. Addis Ababa, Ethiopia.

Dagnachew Gebeyehu. 2008. Environmental and socio-economic impacts and implications of climate change: regional and national. Paper presented to workshop on climate change. September 10, 2008. Bahir Dar, Ethiopia.

Dawit Alemu, Mwangi, W., Mandefro Nigussie, and. Spielman, D. J. 2007. An Analysis of Maize Seed Production and Distribution Systems in Ethiopia's Rift Valley. Ethiopian Institute of Agricultural Research (EIAR) research report. Addis Ababa, Ethiopia.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C., 1999.Livestock to 2020: The Next Food Revolution. International Food Policy Research Institute, Food and Agriculture Organization of the United Nations, and International Livestock Research Institute. IFPRI Food, Agriculture and Environment Discussion Paper 28, Washington, DC, 72 p.

Delve, R.J., Cadisch, G., Tanner, J.C., Thorpe, W., Thorne, P.J. and Giller, K.E., 2001. Implications of livestock feeding management on soil fertility in smallholder farming systems of sub-Saharan Africa. agriculture. *Ecosystems and Environment* 84: 227-243.

Dereje Bacha and Abdissa Gemeda. 2001. Maize marketing in Ethiopia: A review Proceedings of the Second National Maize Workshop of Ethiopia. 12-16 November, 2001. Addis Ababa, Ethiopia.

Devendra, C. and Pezo, D. 2004. Crop-animal systems in Asia and Latin America: Characteristics, opportunities for productivity enhancement and emerging challenges, including comparisons with West Africa. pp 123-159. Proceedings of an international conference on 'Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa'. 19-22 November 2001. Ibadan, Nigeria. International Livestock Research Institute.

Diao, X. and Pratt, A. N. 2007. Growth options and poverty reduction in Ethiopia – an economy-wide model analysis. *Food Policy 32: 205–228.*

Diriba Geleti, Tesema Zewdu, Shimelis Admasu, Demekash Asregid and Senait Yetneberk, 2001. Enhancing the utilization of maize as food and feed in Ethiopia: Availability, limitations and opportunities for improvement. pp. 178-183. Proceedings of the Second national Maize Workshop of Ethiopia. Addis Ababa, Ethiopia. 12-16 November 2001. International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

Dorward, A., Kydd, J., Morrison, J.and Urey, I. 2004. A policy agenda for pro-poor agricultural growth. *World Development* 32: 73–89.

Doss, C.R., Mwangi, W., Verkuijl, H. and de Groote, H. 2003. *Adoption of Maize and Wheat Technologies in Eastern Africa: A Synopsis of the Findings of 22 Case Studies*. CIMMYT Economics Working Paper 03-06.Mexico, D.F.: CIMMYT (International Maize and Wheat Improvement Center).

Dowswell C.R., Paliwal R.L. and Cantrel R.P. 1996. Maize in the Third World. Winrock Development-Oriented Literature Series. WestViewPress. A Division of Harper Collins Publishers.

EARO (Ethiopian Agricultural Research Organization). 2001a. Strategies and priorities for maize research. November 14, 2001. Addis Ababa, Ethiopia.

EARO. 2001b. Livestock research strategy. EARO, Addis Ababa, Ethiopia.

EEA/EEPRI (Ethiopian Economic Association/Ethiopian Economic Policy Research Institute), 2006.Evaluation of the Ethiopian Agricultural Extension with particular Emphasis on Participatory Demonstration and Training Extension System (PADETES). March 2006. Addis Ababa. 270p.

FAO (Food and Agriculture Organization of the United Nations). 2004. Livestock brief – Ethiopia. FAO, Rome.18p.

Friew Kelemu and Girma Mamo. 2001. Suitable zones for growing maize in Ethiopia. pp. 195-202. Proceedings of the Second national Maize Workshop of Ethiopia. Addis Ababa, Ethiopia. 12-16 November 2001. International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

Getahun Degu, Mwangi, W., Verkuijl, H. and Abdishikur Wondimu. 2000. An Assessment of Seed and Fertilizer Packages and the Role of Credit in Smallholder Maize Production in Sidama and North Omo Zones, Ethiopia. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

Gryseels, G. 1988. Role of livestock on mixed smallholder farms in Ethiopian highlands: A casestudy from the Baso and Worena wereda near Debre Berhan. Dissertation, Agricultural University, Wageningen, The Netherlands. 259p.

Habtemariam Kassa. 2003. Livestock and livelihood security in the Hara highlands of Ethiopia: Implications for research and development. Doctoral thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden. 163p.

Hall, A., Mytelka, L. and Oyeyina, B. 2006. Concepts and guidelines for diagnostic assessments of agricultural innovation capacity. United Nations University, UNU-MERIT working paper series No.2006-003. Maasricht, The Netherlands.

Han, J.H. and Harrison, R.W. 2004. A multinomial logit model of consumer perception for biotech food labeling. Selected paper for presentation at the American Agricultural Economics Association annual meeting. Denver, Colorado, 1-4 August 2004.

Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S. and Smits, R.E.H.M. 2007. Functions of innovation systems: A new approach for analysing technological change (in press). *Technological Forecasting and Social Change*. 74: 413-432.

Kebede Mulatu, Gezahegne Bogale, Benti Tolossa, Mossisa Worku, Yigzaw Desalegne and Assefa Afeta. 1993. Maize production trends and research in Ethiopia. pp. 142-154. Proceedings of the First National Maize Workshop of Ethiopia. Addis Ababa, Ethiopia

Langyintou, A.S., Mwangi, W., Diallo, A.O., MacRobert, J., Dixon, J. and Banziger, M. 2008. An analysis of the bottlenecks affecting the production and deployment of maize seed in eastern and southern Africa. Harare, Zimbabwe, CIMMYT.

Legesse Dadi, Mwangi, W. and Franzel, S.,1989. Soccio-economic constraints to maize production in Ethiopia. pp. 436-447. Proceedings of the Third Eastern and Southern Africa Regional Maize Workshop. Nairobi and Kitale, Kenya. September 18-22. Government of Kenya and International Maize and Wheat Improvement Center (CIMMYT).

McCann, J.C., 2005. Maize and Grace: Africa's New Encounter with a New World Crop, 1500-2000. Harvard University Press. Cambridge, Massachusetts, and London. 287p.

MoFED (Ministry of Finance and Economic Development of Ethiopia). 2009. Annual report for macroeconomic developments 2007/2008, MoFED, Addis Ababa, Ethiopia.

Morton, J. and Wilson, T. 2000. The institutional marginality of Livestock production extension: the case of Burkina-Faso. *Livestock Research for Rural Development* 12(1): http://www.lrrd.org/lrrd12/1/mor121.htm .

Mosisa Worku, Hadji Tuna, Mandefro Nigussie and Abera Deressa, 2001. Maize production trends and research in Ethiopia. pp. 171- 187. Proceedings of the Second national Maize Workshop of Ethiopia. Addis Ababa, Ethiopia, 12-16 November 2001. International Maize and Wheat Improvement Center (CIMMYT) and Ethiopian Agricultural Research Organization (EARO).

Mytelka**,** L.K**.** 2000. Local systems of innovation in a globalized world economy. *Industry and Innovation* 77(1): 15-32.

Mytelka, L.K. and Smith, K., 2002. Policy learning and innovation theory: an interactive and co-evolving process. *Research Policy* 31(8-9): 1467-1479.

Oakley P., Pratt B. and Clayton A., 1998. Outcomes and Impact: Evaluating Change in Social development. INTRAC NGO Management and Policy Series No. 6. 177p.

Odame, H. Musyoka, P. and Kere, J. 2008. How National Public Policies Encourage or Impede Agribusiness Innovation: Cases of Maize, Tomato and Dairy in Kenya. A component of the World Bank Institute and the Governments of Denmark and Ireland study on How National Public Policies Encourage or Impede Agribusiness Innovations. Final report. 44p.

Pryanishnikov, I and Katarina, Z. 2003. Multinomial logit models for the Australian labor market. *Australian Journal of Statistics* 4: 267-282.

Raina, R.S., 2003. Disciplines, institutions and organizations: impact assessments in context. *Agricultural Systems* 78 (2): 185-211.

Reddy, B.V.S., Reddy, P.S., Bidinger, F. and Blummel, M., 2003. Crop management factors influencing yield and quality of crop residues. *Field Crops Research* 84:57-77.

Schiere J.B., Baumhardt A.L., Van Keulen H., Whitbread A.M., Bruinsma A.S., Goodchild A.V., Gregorini P., Slingerland M.A. and Wiedemann-Hartwell B. 2006. Mixed crop-livestock systems in semi-arid regions, Ch. 8 in Dryland Agriculture, G.A. Peterson (ed.), 2nd ed. Agron. Monogr. 23. ASA, CSSA, and SSSA, Madison, WI.

Shenk, J.S., Westerhaus, M.O. 1991. Population definition, sample selection and calibration procedures for near-infrared reflectance spectroscopy. *Crop Science* 31: 469-474.

Shiferaw Feleke and Tesfaye Zegeye. 2005. Adoption of improved maize varieties in Southern Ethiopia: Factors and strategy options. *Food Policy* 31:442–457.

Singh, B.B., Larbi, A., Tabo, R. and Dixon, A.G.O. 2004. Trends in development of crop varieties for improved crop-livestock systems in West Africa. pp 371-388. Proceedings of an international conference on 'Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa'. 19-22 November 2001. Ibadan, Nigeria. International Livestock Research Institute.

Speirs, J., Foxon, T. and Pearson, P. 2008. Review of current innovation systems literature in the context of eco-innovation. Task 2 of Work Package 8. OECD.

Spielman, D.J. 2005. Innovation systems perspectives on developing-country agriculture: A critical review. IFPRI-ISNAR discussion paper 2. Washington DC. 58p.

Sumberg, J.2003. Toward a dis-aggregated view of crop–livestock integration in Western Africa. *Land Use Policy* 20:253–264.

Takele Gebre, 1998. Effective use of partnership between NGO's and public sector research and extension programs: Lessons from Ethiopia. pp. xv-xviii. Proceedings of the Sixth Eastern and Southern Africa Regional Maize Conference held on 21-25 September 1998. Addis Ababa, Ethiopia

Tesfaye Zegeye, Bedasa Taddese and Shiferaw Tesfaye, 2001. Adoption of high yielding maize technologies in major maize growing regions in Ethiopia. Research Report No. 41. Ethiopian Agricultural Research organization (EARO). Addis Ababa., Ethiopia. 51p.

UNDP (United Nations Development Program). 2009. Human development report 2009 – HDI rankings. http://hdr.undp.org/en/statistics .

Vavra, M. 1996**.** Sustainability of animal production systems: an ecological perspective. *Animal Science* 74:1418-1423.

Windham, W.R., D.R., Mertens, F.E., Barton. 1989. Protocol for NIRS. Calibration: sample selection and equation development and validation. . pp. 96-103. In: Marten, G.C., Shenk, J.S., Barton, F.E., (Eds). Near infrared reflectance spectroscopy (NIRS): analysis of forage quality. Agriculture Handbook No. 643 (Revised), Suppl. 1, USDA, Washington D.C.

World Bank, 2006. Enhancing agricultural Innovation: How to Go Beyond the Strengthening of Research Systems. Washington DC, USA.

Zinashi Sileshi, Seyoum Bediye, Lulsegede Gebrehiwot, and Tadesse Tekle Tsadik, 1995. Effect of harvesting stage on yield and quality of natural pasture in the central highlands of Ethiopia. pp. 316-322. In: ESAP Proceedings of the. 3rd Annual Conference of the Ethiopian Society of Animal Production (ESAP), Addis Ababa, Ethiopia, 27-29 April 1995. Institute of Agricultural Research.

APPENDIX

Appendix I. Analysis of Variance Tables

Appendix Table 1. Maize global calibration equation statistics for chemistry and NIRS variables

Maize (n = 690)	Calibration samples statistics				Calibration equation statistics		
Variable (% DM)	Min	Max	Mean	Std. Dev	SEC	R^2	SECV
DM	88.891	95.755	92.797	1.078	0.304	0.908	0.344
Ash	4.023	19.600	7.695	2.346	0.469	0.951	0.514
N	0.270	1.669	0.796	0.266	0.042	0.975	0.049
NDF	51.580	84.331	69.191	6.406	1.127	0.969	1.227
ADF	25.798	52.981	38.554	5.642	0.906	0.974	1.020
ADL	0.922	6.653	3.317	0.964	0.338	0.872	0.357
ME	5.417	10.643	8.311	0.917	0.230	0.933	0.259
IOMD	38.307	70.296	55.960	5.699	1.447	0.932	1.626

Appendix Table 2. Analysis of varietal difference on stover yield and quality of 15 maize varieties harvested at the green/*eshet* stage

		Sum of Squares	df	Mean Square	F	Sig.
Ash	Between Groups	5144.47	14	367.462	2.207	.070
	Within Groups	2497.00	15	166.467		
	Total	7641.47	29			
CP	Between Groups	1382.47	14	98.748	2.037	.092
	Within Groups	727.00	15	48.467		
	Total	2109.47	29			
NDF	Between Groups	38201.67	14	2728.690	4.999	.002
	Within Groups	8188.50	15	545.900		
	Total	46390.17	29			
ADF	Between Groups	17400.80	14	1242.914	.641	.794
	Within Groups	29096.00	15	1939.733		
	Total	46496.80	29			
ADL	Between Groups	863.87	14	61.705	5.731	.001
	Within Groups	161.50	15	10.767		
	Total	1025.37	29			
ME	Between Groups	9.22	14	.658	9.590	.000
	Within Groups	1.03	15	.069		
	Total	10.24	29			
IVOMD	Between Groups	427.09	14	30.506	8.745	.000
	Within Groups	52.33	15	3.488		
	Total	479.42	29			
SY	Between Groups	207.84	14	14.846	1.622	.182
	Within Groups	137.32	15	9.154		
	Total	345.15	29			
DSY	Between Groups	128.62	14	9.187	2.034	.092
	Within Groups	67.75	15	4.517		
	Total	196.38	29			
Cellulose	Between Groups	19924.47	14	1423.176	.725	.723
	Within Groups	29440.50	15	1962.700		
	Total	49364.97	29			
Hemi cellulose	Between Groups	35956.67	14	2568.333	1.300	.310
	Within Groups	29631.50	15	1975.433		
	Total	65588.17	29			

Appendix Table 3. Analysis of varietal difference on grain yield and stover yield and quality of 15 maize varieties harvested at the mature/dry stage

		Sum of Squares	df	Mean Square	F	Sig.
Ash	Between Groups	3434.24	14	245.303	2.957	.023
	Within Groups	1244.54	15	82.969		
	Total	4678.77	29			
CP	Between Groups	832.17	14	59.440	1.158	.390
	Within Groups	769.99	15	51.332		
	Total	1602.15	29			
NDF	Between Groups	36553.29	14	2610.949	1.372	.275
	Within Groups	28543.15	15	1902.876		
	Total	65096.44	29			
ADF	Between Groups	32230.28	14	2302.163	4.723	.003
	Within Groups	7310.84	15	487.389		
	Total	39541.11	29			
ADL	Between Groups	2261.66	14	161.547	16.014	.000
	Within Groups	151.32	15	10.088		
	Total	2412.99	29			
ME	Between Groups	7.74	14	.553	7.352	.000
	Within Groups	1.13	15	.075		
	Total	8.87	29			
IVOMD	Between Groups	346.56	14	24.754	6.536	.000
	Within Groups	56.81	15	3.787		
	Total	403.36	29			
SY	Between Groups	127.05	14	9.075	3.127	.018
	Within Groups	43.54	15	2.903		
	Total	170.59	29			
DSY	Between Groups	63.62	14	4.545	4.635	.003
	Within Groups	14.71	15	.980		
	Total	78.33	29			
GY	Between Groups	61.72	14	4.409	.980	.513
	Within Groups	67.47	15	4.498		
	Total	129.19	29			
Cellulose	Between Groups	21123.20	14	1508.800	2.545	.042
	Within Groups	8894.00	15	592.933		
	Total	30017.20	29			
Hemi cellulose	Between Groups	36616.87	14	2615.490	1.923	.111
	Within Groups	20396.50	15	1359.767		
	Total	57013.37	29			
CY	Between Groups	2.84	14	.203	1.401	.262
	Within Groups	2.17	15	.145		
	Total	5.01	29			
TAGBM	Between Groups	155.64	14	11.117	.843	.622
	Within Groups	197.71	15	13.180		
	Total	353.35	29			

Appendix Table 4. Effect of stage of maturity at harvest on the yield and quality of stovers of 15 maize varieties

		Sum of Squares	df	Mean Square	F	Sig.
Ash	Between Groups	22.38	1	22.378	.132	.718
	Within Groups	9165.46	54	169.731		
	Total	9187.84	55			
CP	Between Groups	6136.26	1	6136.258	104.872	.000
	Within Groups	3159.64	54	58.512		
	Total	9295.89	55			
NDF	Between Groups	192712.18	1	192712.179	98.772	.000
	Within Groups	105358.67	54	1951.086		
	Total	298070.85	55			
ADF	Between Groups	211412.58	1	211412.583	142.330	.000
	Within Groups	80209.87	54	1485.368		
	Total	291622.45	55			
ADL	Between Groups	3882.78	1	3882.780	63.253	.000
	Within Groups	3314.77	54	61.385		
	Total	7197.55	55			
ME	Between Groups	10.72	1	10.719	30.635	.000
	Within Groups	18.89	54	.350		
	Total	29.61	55			
IVOMD	Between Groups	431.24	1	431.235	26.682	.000
	Within Groups	872.74	54	16.162		
	Total	1303.98	55			
SY	Between Groups	415.83	1	415.830	44.321	.000
	Within Groups	506.64	54	9.382		
	Total	922.47	55			
DSY	Between Groups	233.54	1	233.539	46.598	.000
	Within Groups	270.64	54	5.012		
	Total	504.18	55			
Cellulose	Between Groups	164594.57	1	164594.571	118.275	.000
	Within Groups	75147.64	54	1391.623		
	Total	239742.21	55			
Hemi cellulose	Between Groups	75.45	1	75.446	.036	.850
	Within Groups	112847.68	54	2089.772		
	Total	112923.13	55			

Appendix II. The Questionnaire Used to Collect Household Level Data

I. FARMER CHARACTERISTICS

A. Farm Household Characteristics

1. Age of the household head (in completed years)__________
2. Sex of the household head
   1. Male 2.Female
3. Marital status of the household head
   1. Married
   2. Divorced
   3. Single
   4. Widowed
4. Education level of the household head (years of schooling/grade)________________
5. Number of years that the head of the household has been living in this district ______.
6. When did the head of the household start farming for his/her own (experience of farming)? (Year)______.
7. Did head of the household have some social position in the community so far?
   1. Yes 2. No
8. If yes, what is his/her position in the community?
   1. Political leader
   2. Spiritual leader
   3. Elder

B. Labour Availability

9. Total family size: Male __________ Female____________

Sex	Age group					
	0-14		15-64		>64	
	Working in the farm	Not working in the farm	Working in the farm	Not working in the farm	Working in the farm	Not working in the farm
Male						
Female						

F= Full time P= part time

10. Number of family members working off-farm
    Male ____________ Female _____________
11. Do you have labour shortage?
    1. Yes 2.No

(***If 'No' to 11, go to18***)

12. If yes, during what months of the year?

Months of labour shortage	For what activities?

13. If yes to question 11, how do you manage labour shortage?
    1. Hiring labour
    2. Other (specify) ____

14. If labour is hired, what type of labour do you hire?
    1. Permanent
    2. Casual
    3. Both
15. If permanent, how much do you pay per annum? (Birr/kind)____
16. If casual, how much do you pay per day? (Birr/kind)______

Do you get labour to hire when you are in need?
    1. Yes   2. No

17. Where is the source of labour for hiring? 1. Members of the poor from the local community 2. People migrating from other locations 3. Other (specify)____
18. In which activities your female family members participate?
    1______________________2. ______________________
    3. ______________________ 4. ______________________
19. In which activities are children <14 years involved?
    1.____________2. _____________3. ___________4. _____________

C. Land holdings and use

20. Total farm size ______________(ha / 'Kert'/ other local unit (specify))
    Cultivated ________________(unit)
    Grazing ________________(unit)
    Fallowed ________________(unit)

21. Land tenure
    Owned ________________(unit)
    Family ________________(unit)
    Shared in ________________(unit)
    Shared out____________________
    Rented in ________________(unit)
    Rented out____________________
    Other (specify) ________________(unit)

22. Do you think your land is adequate to produce enough crops to sustain your family?
1. Yes 2. No
23. If no, from where did you get additional land to fulfil your family needs?
1. Rent
2. Share cropping (Share-in)
3. Others (specify)____

D. Non-farm income

24. Do you have non-farm income source/s? 1. Yes 2. No
(If 'No' to 24, go to Section II)
25. If yes to 24, please indicate the source, amount of money from and the purposes you expend the income at.

Activity/source of non-farm income	Average amount obtained per annum	Purposes income expended

II. FARM CHARACTERISTICS

A. Crops
26. Provide information regarding area and yield of crops in 1999 E.C

. Plot No	Size	Crop grown	Yield		End use		End use of residue		
			Meher	Belg	Consumpt	Sale	Feed	Fuel	Other (specify

Maize variety preference
27. If you are growing maize, which type?
1. Local
2. Improved
3. Both

28. If you grow improved maize, which variety of maize did you grow (in the past years) and why do you prefer? (encircle the variety and mark an 'X' in the 'reasons' column)

Variety Preferred	Reasons for preference			
	High grain yield	Fodder value	Disease and pest resistance	Other (specify)
BH660				
BH540				
BH140				
BH542				
PHB 30H83 (pioneer)				
Kuleni				
Arganne,				
Hora				

29. Under normal conditions, which is the most preferred variety of maize that you like to grow?
(reason/s)____
____
____
____

30. Is the preferred variety readily available? 1. Yes 2. No
31. If no to question 30, what is the source of seed for your preferred variety?
    1. Share from a relative
    2. Recycle seeds
    3. Other____
32. Is/are there variety/varieties that you have tried but stopped planting?
    1. Yes 2. No

33. If yes to 32, which maize varieties did you try but stopped planting (please mark with an 'X')?

Variety tried but stopped growing	Reason/s			
	Low grain yield	Low Fodder value	Susceptibility to disease and pest	Other (specify)

Input use

34. Have you ever purchased inputs from the open market? 1. Yes 2. No
35. If yes to question 34, what concerns do you have?
    1. Higher price
    2. Lower quality
    3. Other (specify) ______________________
36. What is the trend of your input use? 1. Increasing 2. Decreasing
(Reasons)______________________________________
____

Maize market

37. Do you sell maize? 1. Yes 2.No
38. If yes to 37, to whom?
    1. Anybody on the open market
    2. Cooperatives
    3. Local traders
39. If you sell to cooperatives, what benefits do you get?______________________________________
    ____

40. For selling your produce, what means of transport do you use? 1. Pack animals 2.Vehicle 3. Animal drawn carts

41. What are the key issues in maize production?______________________________________
    ____
    ____
    ____
    ____

B. Livestock

42. Do you keep livestock?
    1. Yes 2.No

43. If yes to 42, state the types and number of livestock owned and indicate the trend in number and productivity through time since you owned by saying ‘increasing’ and ‘decreasing’.

Types of livestock		**Number**	**Trend**	
			Number	**Productivity**
1	Calf			
2	Ox			
3	Cow			
4	Heifer			
5	Bull			
6	Sheep			
7	Goat			
8	Donkey			
9	Horse			
10	Mule			

Livestock feeding

44. Please fill the following feed calendar

Months of relative feed abundance	Months of decreasing feed availability	Months of less sever feed shortage	Months of severe feed shortage

45. During periods of severe feed shortage, what do you do to feed your livestock (ruminant + equines)?
    1. Feed on reserved crop residue
    2. Feeding tree leaves
    3. Send a portion of the animals to a relative who lives in an area of relative feed availability
    4. Buy feed
    5. Sell some of them
    6. Other (specify)____
46. Have you ever planted an improved forage crop on your land?
    1. Yes 2. No
    (If ‘No’ to 46, go to49)
47. If yes, which type(s) of forage have you tried on your field?
    ____
48. Who introduced the forages? _______________________________
49. Have you practiced fattening? 1. Yes 2. No

50. If yes to 48, which species and what diets/feeds? 1. Cattle 2. Sheep 3. Goats
Diets/feed____
____

Veterinary issues

51. Mention three most important animal diseases that affect your livestock.
    1.____________________________________
    2. ____________________________________
    3.____________________________________

52. Do you have an access to veterinary services?
    1. Yes 2. No
53. If yes, what is the distance to the nearest vet clinic from home? ______km.

54. Do veterinarians visit your livestock?
    1. Yes 2. No
55. If yes, how frequent (number of days per year)? _______________
56. Have you tried to rear crossbred animals? 1. Yes 2.No
57. If no to 56, why?
    1. Lack of money for initial investment
    2. Land shortage for grazing/feeding
    3. Lack of labor for caring
    4. Other (specify)____

58. If yes to 56, which breed?____________________________________
59. Have quit doing so?
    1. Yes 2. No
60. If yes to 59, what are the reasons for?____
    ____
    ____
61. Did you get money from the sale of live animals/products (power inclusive)
    1. Yes 2. No
62. If yes to 60, for what purposes do you use the money? ________________
    ____
    ____
63. What are the key issues in livestock production?____
    ____
    ____

III. INNOVATION SYSTEM: ACTIONS, INTERACTIONS AND RULES OF ENGAGEMENT

64. Do DAs/extension agents visit your maize farm during the growing season?
    1. Yes 2. No
65. If yes, how frequent (number of times per growing season)?
    ____
66. Have you attended any training on livestock production practices in the past?
    1. Yes 2. No
67. If yes, would you please mention the type of training?
    ____
    ____
68. With which organizations (GOs, NGOs, CBOs…) do you have contacts? (list them and their contributions to your farming operations)

Organization	Purpose	Guidelines	Special arrangement

69. Do you get credit service? 1. Yes 2. No (***If 'No" to 69, go to72***)
70. If yes, for what purposes do use it?
    1. Input (fertilizer and maize seeds) purchase
    2. Improved livestock purchase
    3. Purchase of farm machinery
    4. Other (specify)____
71. What are the problems you face in the credit system you are exposed to?
    1. High interest rate
    2. Require collateral
    3. Request to pay debt earlier in the dry season
    4. Any other (specify)____
72. Do you use maize production inputs (fertilizer, seeds, herbicides…)? 1. Yes 2. No
73. If yes, where do you get the inputs from?
    1. Cooperatives 2. Private suppliers

3. NGOs 4. Other(specify)___________________________________

74. How do you purchase the inputs? 1. On cash 2. On credit?

75. If on credit, where do you get the credit?
   1. Cooperatives
   2. Microfinance organizations
   3. NGOs
   4. Bank
   5. Other (specify)____

76. How do you describe the loan arrangement?
   1. Smooth
   2. Fairly smooth
   3. Problematic

77. Have you ever failed to pay debts from the sale of crops?
   1. Yes 2. No

78. If yes, what did you do? 1. Sold livestock 2. Rented out land
   3. Sold other household belongings 4. Other(specify)__________________________

79. What is the distance to your nearest extension office from home? ___________km.

80. What is the distance to your nearest market from home? _____________km.

81. From where do you learn about improved farming practices?
   1. MoARD extension agents 2. Researchers
   3. Other farmers 4. NGOs 5. Mass media
   6. Other____

82. Have you ever participated in a training of farmer groups? 1. Yes 2. No

83. If yes, on which enterprise?
   1. Crops
   2. Livestock
   3. Both

84. Did you participate in farmers' field days/demonstration/verification processes?
   1. Yes 2. No

85. If yes to 84, please specify the enterprises and who organized the processes.
   ____
   ____
   ____

86. To which media are you exposed?
   1. Radio
   2. TV
   3. News paper

87. Have you learnt about improved agricultural production from the media?
   1. Yes 2. No

88. If yes, on which sub-sector?
   1. Maize
   2. Livestock 3. Both